Sorensen
A Raytheon Company

Instruction Manual for

XT Series Power Supplies

This manual covers models:

7-6	30-2
15-4	60-1
20-3	120-0.5

Document Number 1059315 Rev A (1/86)

SORENSEN COMPANY LIMITED WARRANTY

All XT Series power supplies manufactured by Sorensen Company Inc. are guaranteed for three (3) years from the date of delivery against defects in material and workmanship. This does not apply to products damaged through accident, abuse, misuse, or unauthorized repair. Sorensen shall not be liable for any special or consequential damage of any nature. The manufacturer will repair or replace the non-conforming product or issue credit, at its option, provided the manufacturer's inspection establishes the existence of a defect. Packing, freight, insurance and other charges incurred in returning the defective products to the manufacturer will be paid by the purchaser. If any questions arise concerning the warranty, check with Sorensen prior to taking any action.

When information, assistance or authorization is required, refer to the model and serial number on the back of the unit when contacting Sorensen.

Model: _____

Serial Number: _____

Sorensen XT Series Power Supply

TECHNICAL MANUAL

Release 6/88

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Table of Contents

1. Features and Specifications		PAGE
1.1 Purpose	.....	1-1
1.2 Description	.....	1-1
1.3 Operating Modes	.....	1-1
1.4 Equipment Features	.....	1-2
1.5 Specifications	.....	1-2
1.6 Optional Accessories	.....	1-4
2. Installation and Operation		
2.1 General	.....	2-1
2.2 Initial Inspection	.....	2-1
2.3 Installation	.....	2-1
2.4 Electrical Check	.....	2-2
2.5 Standard Operation	.....	2-3
2.6 Operation with Options	.....	2-7
2.7 Operation with IEEE488	.....	2-11
3. Theory of Operation		
3.1 Power Circuit	.....	3-1
3.2 Meter Circuit	.....	3-3
3.3 Option Circuits	.....	3-3
4. Maintenance		
4.1 General	.....	4-1
4.2 Periodic Servicing	.....	4-1
4.3 Test Equipment Required	.....	4-1
4.4 Troubleshooting	.....	4-1
4.5 Calibration	.....	4-10
5. Drawings and Parts Lists		
5.1 General	.....	5-1
5.2 Parts Ordering	.....	5-1
5.3 A1 Assembly Parts	.....	5-4
5.4 A2 Assembly Parts	.....	5-6
5.5 A3 Assembly Parts	.....	5-12
5.6 A4 Assembly Parts	.....	5-16
5.7 Main Assembly Parts	.....	5-19

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List of Illustrations

FIGURE			PAGE
2-1	Controls and Indicators	.....	2-2
2-2	Temperature Derating	.....	2-6
2-3	Options M5 and M7 Connector	.....	2-7
2-4	Option M9 Connector and Controls	.....	2-11
5-1	Assembly Interconnection	.....	5-2
5-2	A1 & A2 Assembly Schematics	.....	5-3
5-3	A3 Assembly Schematic	.....	5-11
5-4	A4 Assembly Schematic	.....	5-15

List of Tables

TABLE			PAGE
2-1	M5 and M7 Connector, J305, detail	.....	2-8
2-2	M9 Connector detail	.....	2-12
2-3	Serial Poll Status Byte	.....	2-13

SECTION 1

FEATURES AND SPECIFICATIONS

1.1 PURPOSE

This manual contains operation and maintenance instructions for the XT Series of high performance laboratory power supplies. The series consists of six basic models which can be combined into dual, triple, and quadruple configurations in any combination of models. The basic models are designated by an XT prefix, followed by an S for a single supply,D for a dual supply, T for a triple supply, or Q for a quadruple supply. These three letter prefixes are followed by the voltage and current rating of the individual unit. For example, the XTS 7-6 model number signifies that this is a single supply rated at 0 to 7 Vdc output at a maximum of 6 Amps. Similarly, the XTD 120-.5 is a dual supply rated at 0 to 120 Vdc per individual unit at a maximum output of 0.5 Amps.

Five major sections form the manual divisions:

Section 1 - Description of series features and specifications.

Section 2 - Installation and operating instructions.

Section 3 - Theory of operation.

Section 4 - Maintenance and service procedures.

Section 5 - Drawings, schematics, and parts lists.

1.2 DESCRIPTION

The XT Series of laboratory power supplies are designed to provide high stability, continuously variable output voltage and current for a broad range of development and system requirements. The XT Series employs precision linear regulator technology to achieve precise regulation and low output noise levels.

1.3 OPERATING MODES

The XT Series has two basic operating modes: Constant Voltage and Constant Current. In the former, th the output voltage is regulated at the front panel selected value, and the output current varies with the load. In constant current operation, the output current is regulated at the selected value and the output voltage varies as a function of the output load.

1.3.1 Automatic Crossover

The automatic crossover system enables the unit to transfer operating modes as a function of load requirements. If, for example, the load current attempts to increase above the setting of the current adjust control, the unit will switch automatically from the voltage to the current regulating mode. If the load requirements are lowered, return to the voltage mode will occur automatically.

1.3.2 Sense Connections

To compensate for losses in power leads connected to the output, sense connections are provided beside the output binding posts. Connecting the positive and negative sense lines to the point where the metered output voltage is desired will automatically compensate for the voltage losses in the main power leads (provided the sum of these losses do not exceed 0.5 volts). With the voltmeter reading 10.0 volts, for

example, and having the sense lines connected directly to the load, the load voltage will stay at exactly 10.0 volts regardless of the voltage drops in the power leads, no matter how much current is drawn. Do not use the sense connections without the normal power lead connections to the output terminals, and avoid reversing positive and negative lead connections.

1.4 EQUIPMENT FEATURES

- o Simultaneous digital display of both voltage and current.
- o Unique analog bar graph displays of both voltage and current for ease of monitoring transient changes under varying loads.
- o Ten turn potentiometer voltage control allowing high resolution setting of the output voltage.
- o Current adjust potentiometer allowing current limiting which is fully adjustable from zero to the rated output.
- o Automatic mode crossover into current or voltage mode.
- o Impedance-switched remote sensing allowing the voltage at the load to be displayed without switch ambiguity.
- o Optimized output connections: 5-way binding posts on 0.75 inch centers - dual banana plug, with or without safety ground, and 4 position terminal strip for rear output.
- o Flexible output configuration: Multiple units can be connected in parallel or series without damage and are short circuit proof.
- o Modular design allowing easy replacement or repair of plug connected sub-assemblies.
- o A broad range of optional features:
  - Over Voltage Protection (OVP)
  - External TTL Shutdown
  - Remote Voltage & Current Programming
  - Audible Mode Indication
  - Rear Access Connector
  - IEEE488 Interface
  - Output Tracking

1.5 SPECIFICATIONS

1.5.1 Electrical Specifications

Output voltage and current ratings for each model (single unit) are as follows:

Model Number	Voltage	Current*
XTS 7-6	0 - 7V	0 - 6A
XTS 15-4	0 - 15V	0 - 4A
XTS 20-3	0 - 20V	0 - 3A
XTS 30-2	0 - 30V	0 - 2A
XTS 60-1	0 - 60V	0 - 1A
XTS 120-0.5	0 - 120V	0 - 0.5A

* measured at ambient temperature. Above 30oC, see fig 2-2.

	Voltage Mode	Current Mode
Line Regulation (103-125VAC)	0.01% + 2mV	0.01% + 250uA
Load Regulation (0-100% Remotely Sensed) (10-100%)	0.01% + 2mV	 0.01% + 250uA
Noise and Ripple (Isolated Tracking)	<1mV rms <2mV rms	<2mA rms
Temperature Coefficient (after 30 minutes)	0.015%/°C	0.02%/°C
Drift (Over 8 hrs. after 30 minutes)	0.02%	0.03%
Transient Response (recovery to 0.05% BAND) +/-50% load change in the range of 25% to 100% of rated load.	<100uSec	
Ambient Operating Range	0-30°C for full rated output. See fig 2-2 for derated operation to 70oC	
Storage Temperature	-55 to +85°C	
Humidity Range	0 to 80% RH	
Voltage Resolution	0.02%	
Meter Accuracy	1% of full scale + 1 count	
Input	115 Vac +/- 10%, 57-63 Hz 1.2A	

Maximum Float Voltage Above Ground For Outputs	500 Vdc

1.5.2 Mechanical Specifications

	Height	Width	Depth	Weight
Single Supply	132mm 5.2in	109mm 4.3in	297mm 11.7in	3.1kg 6.8lbs
Dual Supply	132mm 5.2in	216mm 8.5in	297mm 11.7in	6.0kg 13.2lbs
Triple Supply	132mm 5.2in	325mm 12.8in	297mm 11.7in	9.0kg 19.8lbs
Quad Supply (rack mountable)	132mm 5.2in	436mm 17.0in	297mm 11.7in	12.4kg 27.2lbs

1.6 OPTIONAL ACCESSORIES

The available options for the XT Series power supplies are: Over Voltage Protection (OVP), Remote ON/OFF, Isolated Tracking, Remote Voltage Programming and/or Current Programming, Audible Mode Indicator, and IEEE488 Interface.

The quad configuration comes with 19" rack mounting flanges and may be used rack mounted or free standing. Single, dual and triple configurations are configured for benchtop use but may be 19" rack mounted using an optional rack mounting adaptor.

Options are available in three different configurations. Option M5 provides overvoltage protection (OVP), remote programming, remote ON/OFF, and rear panel output terminals. Option M7 provides all of the features in option M5 plus isolated tracking and audible mode indication. Option M9 includes the IEEE488 interface allowing output voltage and current programming directly in volts and amperes with 12-bit resolution from IEEE488/GPIB equipped controllers. Overvoltage protection and 8-bit digital readback of voltage and current are also provided with this option.

1.6.1 Option Specifications

Over Voltage Protection	Trip Voltage range: 3.0V to full output plus 10%.
Remote ON/OFF (Option M5 & M7)	Standard TTL: (Isolated) High = 3V minimum, output is OFF Low = 0.8V maximum, output is ON
Isolated Tracking (Option M5 & M7)	Tracking Error: Fixed ratio of 1% +/-1 count on each voltage display.
Remote Programming (Option M5 & M7)	Programming Voltage Coefficient: Voltage: 1V/10% of output +/-.1% Current: 1V/10% of output +/-.1%

Rear Panel Connectors	
(Option M5 & M7)	25 pin female D-sub connector
(Option M9)	IEEE488 connector and 4 terminal output barrier strip
Programming Resolution	
(Option M9)	Voltage: +/- 0.03% Current: +/- 0.03%
Programming Accuracy	
(option M9)	Voltage: +/- 0.05% Current: +/- 0.05%
Readback Accuracy	
(Option M9)	Voltage: +/- 0.5% Current: +/- 0.5%

SECTION 2

INSTALLATION AND OPERATING INSTRUCTIONS

2.1 GENERAL

After unpacking, an initial inspection should be performed to ensure that the unit is in good working order. If it is determined that the unit is damaged, the carrier should be notified immediately. Repair problems should be directed to the Service Department, Sorensen Co., 46 BARFOOT ROAD, HUDSON N.H. (603) 881-5300.

2.2 INITIAL INSPECTION

The power supply comes complete with an IEC power cord set and technical manual. The equipment should be inspected for damage as follows:

a. Inspect panel and chassis for dents, and other signs of obvious damage.

b. Turn front panel controls from stop to stop. Rotation should be smooth.

c. Test the action of the power switch. Switching action should be positive.

d. If internal damage is suspected, remove the cover and check the components and printed circuit board for damage. Reinstall the cover.

2.3 INSTALLATION

Before connecting the unit to an AC outlet, make sure that the power switch is in the extended (OFF) position and the Voltage and Current controls are in their fully counter clockwise positions. The AC line voltage should be 117V 60Hz nominal.

A voltage control mode indicator (green) is located above the voltage control knob. A current limit mode indicator (red) is located above the current limit adjust knob. The power supply outputs are red and black binding posts. The green binding post is connected to chassis and line ground.

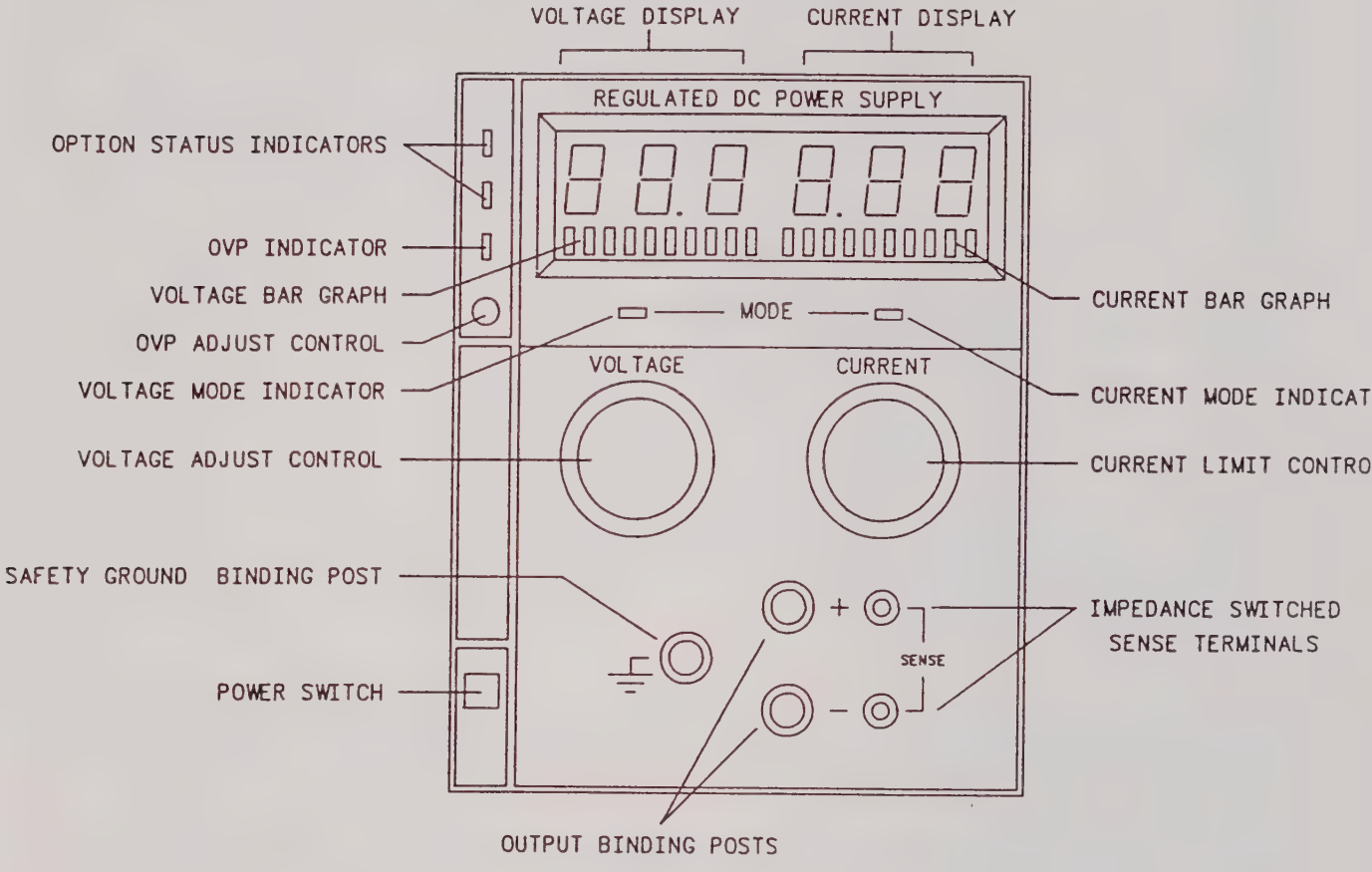
Connect either the (+) or (-) terminal to the ground terminal depending upon the desired output voltage polarity using a short wire for this connection. If the output voltage is to be biased relative to ground, it is recommended that a 0.01uF capacitor of sufficient voltage rating (200-1000V) be used in place of the shorting connection. The power supply outputs may be biased by up to a maximum of +500Vdc with respect to line safety ground.

Plug the line cord into a grounded AC outlet. Push the power switch to turn on the power supply. The red current LED will light and the display readings will remain zero.

To use the power supply in the Constant Voltage mode, turn the current control to its extreme clockwise position and set the voltage control to the desired voltage. To operate the supply in the Constant Current mode, turn the voltage control 1/2 turn clockwise and the current control fully counter clockwise. Connect a shorting lead across the output terminals and set the desired maximum value of current limit by turning the control clockwise. Then disconnect the shorting lead from the output terminals. The power supply will now automatically switch into the current limiting mode (current regulation) as soon as the preset current level is reached and will not exceed this level at any voltage setting. As soon as the supply starts operating in current mode, the red current mode LED will turn on.

Figure 2-1

Front Panel, Controls and Indicators



2.4 ELECTRICAL CHECK

2.4.1 Voltage Mode

To check voltage mode operation, proceed as follows:

a. Rotate VOLTAGE and CURRENT controls fully counter clockwise.

b. Connect a DC voltmeter, rated better than .5% accuracy, to the front panel binding posts (+ and -).

c. Connect the IEC power cord set to the unit, then to an appropriate power source and set the POWER switch to ON.

d. Rotate the CURRENT control 1/2 turn clockwise. Slowly rotate the VOLTAGE control clockwise and observe the digital displays. The control range should be from zero to maximum rated output. Compare the test meter with the voltage display on the left. Observe the bar graph meter to see that it tracks as the voltage rises and that the voltage mode indicator light is ON.

e. Set the POWER switch to OFF.

2.4.2 Current Mode

To check current mode operation, proceed as follows:

a. Rotate VOLTAGE and CURRENT controls fully counterclockwise.

b. Rotate the VOLTAGE control 1/2 turn clockwise.

c. Connect a DC ammeter between the front panel binding posts (+ and -). Select leads of sufficient current carrying capacity and an ammeter range compatible with the unit's rated current output. The ammeter should have an accuracy of better than .5%.

d. Set the POWER switch to ON.

e. Rotate the CURRENT control slowly clockwise. The control range should be from zero to the maximum rated output. Compare the test meter reading with the reading on the panel current meter. Also check that the current bar graph display follows the rise in current and that the current mode indicator light is ON.

f. Set the POWER switch to OFF.

2.5 STANDARD OPERATION

Reliable performance of the power supply can be obtained if certain basic precautions are taken when connecting it for use on the lab bench or installing it in a system.

To obtain a stable, low noise output, careful attention should be paid to factors such as conductor ratings, system grounding techniques, and the particular way the AC input, DC output, and remote sensing connections are made.

A conductor size that satisfies the current rating requirements should be used. To overcome impedance and coupling effects, however, larger gauge wire and short leads are recommended.

2.5.1 Grounding

Proper grounding connections should be made to avoid paths between separate ground points. To avoid ground loop problems, there must be only one ground return point in a power system. If the load is ungrounded, the appropriate output binding post may be grounded to the green safety ground binding post on the front of the unit.

2.5.2 Load Connection

Proper connection of distributed loads is an important aspect of power supply application. A most common mistake is to connect leads from the power supply to one load and then from that load to other loads. In this parallel power distribution method, voltage at each load depends on the current drawn by the other loads and DC ground loops are developed. Except for low current applications, this method should not be used.

A preferred way to distribute power is by the radial distribution method in which power is connected individually to each load. In the radial method, a single pair of terminals are designated as the positive and negative distribution terminals. This pair of terminals may be the power supply output terminals, the load terminals, or a distinct set of terminals specially established for distribution. In this scheme, there are no ground loops and little effect of one load upon the other.

2.5.3 Multiple Supplies

The XT Series power supplies may operated with outputs in series or parallel with no external protection. These supplies consist of fully independent power supplies which have only the power switch in common. For independent operation of each supply, the procedure as previously outlined applies.

2.5.4 Series Operation

The series connection is used to obtain a higher voltage single output supply. Connect the (-) terminal of one supply to the (+) terminal of the next supply. The total voltage available is the sum of the maximum voltages of each supply (add voltmeter readings). Connect the positive or negative terminal to either of the ground terminals depending on the desired output voltage polarity.

The maximum current available to the load is equal to the current of the lowest rated supply.

2.5.5 Parallel Operation

The parallel connection is used to obtain a higher current single output supply. Set all outputs to the same voltage before connecting the (+) and (-) terminals in parallel. The total current available is the sum of the maximum currents of each supply. DO NOT parallel outputs which have overvoltage protection installed. (Blocking diodes in series with the output may be used to parallel such outputs). The maximum voltage available at the load is equal to the voltage of the lowest rated supply. When two supplies are paralleled, the supply with the higher voltage setting will be in the current limiting mode, while the other supply controls the output voltage. Output voltage noise and regulation will be degraded slightly with parallel connections.

2.5.6 Split Supply Operation

The split connection is used to obtain two positive voltages with a common ground, or a positive-negative supply. To obtain two positive voltages, connect the ground of one supply to the negative terminals of both supplies. The positive terminals will supply the required voltages with respect to common.

To obtain a positive-negative supply, connect the ground of the left section to the negative terminal and the ground of the right section to the positive terminal. The left section (+) terminal then provides a positive voltage relative to ground and the right section (-) terminal a negative voltage. The current limits (current controls) can be set independently. The maximum current available in split operation is equal to the lowest individual rating of the supplies.

2.5.7 Remote Sensing

Remote sensing permits regulation with respect to the point of load connection, rather than at the output terminals of the power supply. It corrects for load lead drops of up to a total of 0.5 volts. With remote sense leads in place, the displayed voltage is at the load. With the sense lines disconnected, the displayed voltage is at the output terminals. Sense lines should be a twisted pair, or shielded twisted pair for lowest noise. Do not operate the supply with the sense lines connected without also connecting the regular power lines.

2.5.8 Safe Operating Area

The XT Series safe operating area at various temperatures is shown in Figure 2-2. The XT power supply must be operated at or below the lines shown at the ambient temperature indicated. The sawtooth nature of the curves is due to the characteristics of the "Power-OR" series pass output circuitry (see section 3, para. 3.1.3).

To determine the safe operating area of temperatures between 30-Deg C and 70 Deg C, not indicated in Figure 2-2, use the following procedure.

1. Plot the horizontal constant temperature - constant current line for the ambient operating temperature. These lines derate linearly at 2.5% of I-out per Deg C using the 30 Deg C curve shown in Figure 2-2 as the base line.

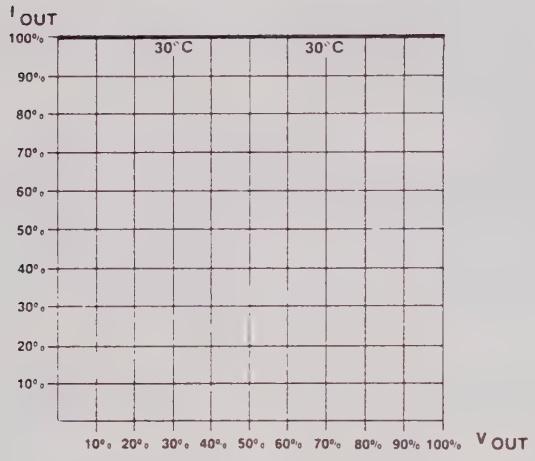
2. Next plot the two diagonal "Power-OR" lines.Using the 70 Deg C curve shown in Figure 2-2 as the base line the diagonal lines in the 0 to 50% of V-out region have a positive slope of 1.6% I-out per 1.0% V-out.The slope in the 60 to 100% of V-out region is a positive 2.0% I-out per 1.0% V-out. This applies at all ambient operating temperatures from 30 Deg C to 70 Deg C maximum. The intersection point of the diagonal lines to the constant I-out axis increases at 0.5% I-out per Deg C as the ambient operating temperature decreasesfrom 70 Deg C to 30 Deg C.

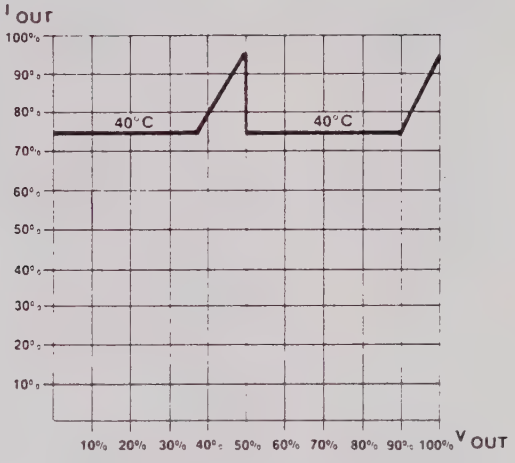
3. Next draw a vertical line at V-out equal to 50% from the constant temperature - constant current line, plotted in step 1, to the intersection of the first region diagonal "Power-OR" line plotted in step 2.

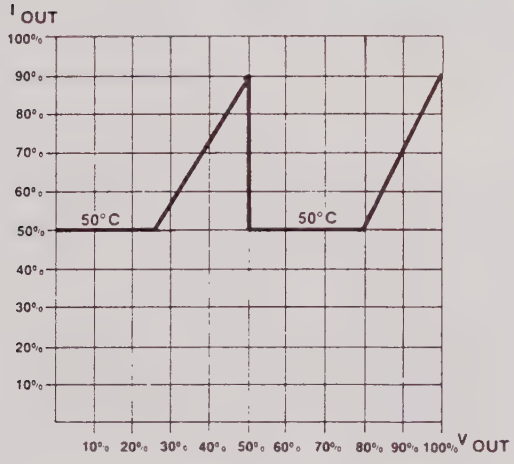
4. The four lines plotted now form the safe operating area for the ambient operating temperature. This can be seen in the 40 Deg C, 50 Deg C, and 60 Deg C curves shown in Figure 2-2.

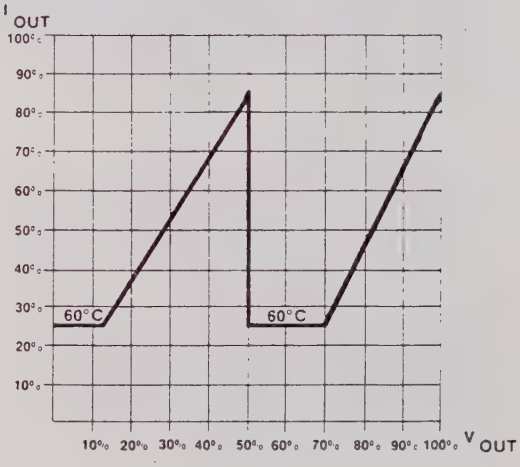
Figure 2-2

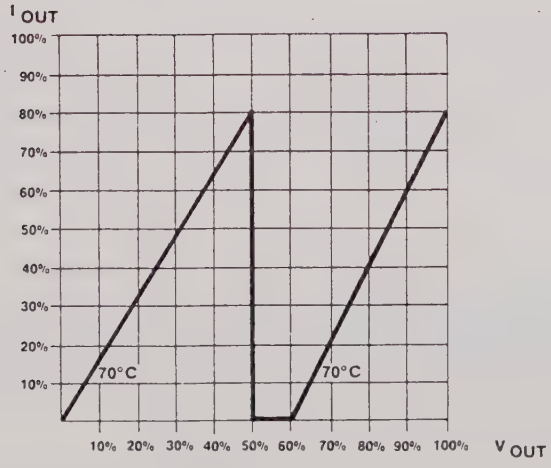
Temperature Derating











NOTE

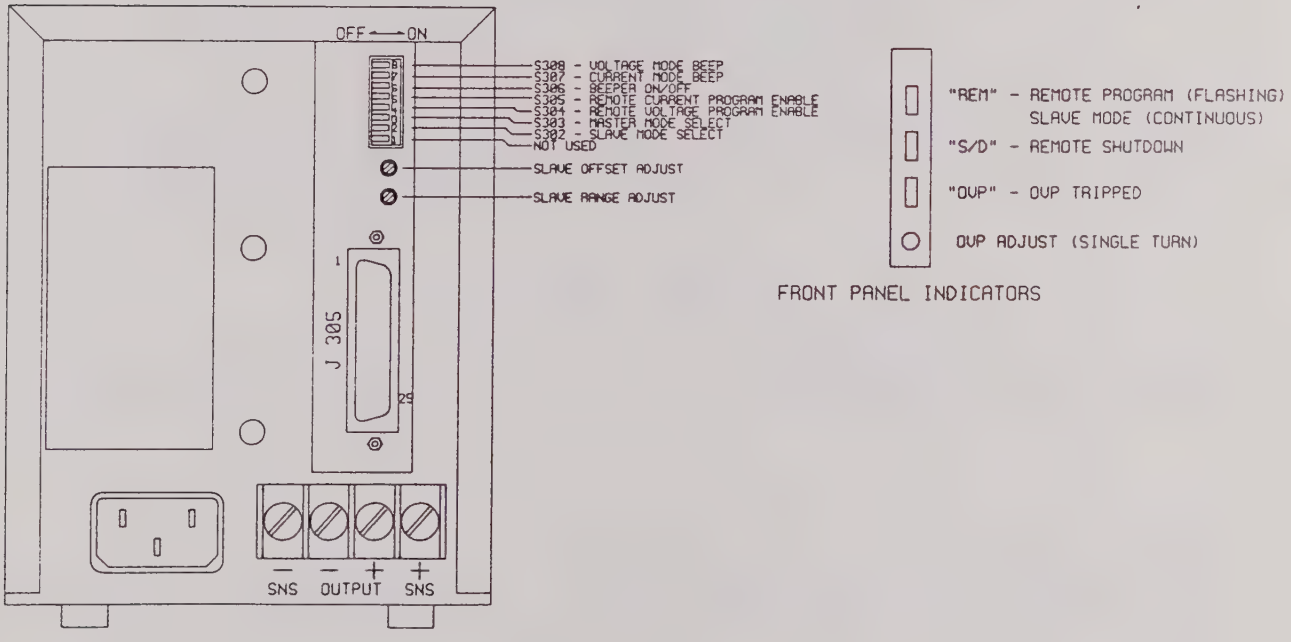
Safe operation of ranges at or below temperature lines for any given percentage of total V-out will determine current available.

2.6 OPERATION WITH OPTIONS M5 OR M7 INSTALLED

Two analog programming option card versions are available as outlined in section 1.6. Be sure to check which features are available on your unit before following the directions below.See Figure 2-3 and Table 2-1 for details on the connector and controls.

Figure 2-3

Connector,Controls and Indicators



To use this option, a mating 25 pin D-subminiature connector (included) and cable must be constructed, using the following connector pin-out table:

Table 2-1
Option card connector J305 Detail
(D-subminiature 25 pin Female)*

Pin Number	Function
1	N/C
14	N/C
2	External Shutdown Return
15	External Shutdown Input (TTL High Level)
3	N/C
16	External Current Programming Input(0to10 volts)
4	External Programming Return
17	External Voltage Programming Input(0to10 volts)
5	External Programming Return
18	N/C
6	+10V Reference (2 mA maximum)
19	N/C
7	N/C
20	N/C
8	Tracking Bus (Option M7)
21	N/C
9	Tracking Bus (Option M7)
22	Positive Sense
10	Positive output
23	Positive Output
11	Positive Output
24	Return
12	Return
25	Return Sense
13	Return

NOTE: Do not tie pins 4 or 5 to any other points on J305.

*Mating connector - 25 pin male ITT Cannon DB25P or equivalent.

2.6.1 Over Voltage Protection (OVP) (Options M5 & M7)

The OVP circuit allows for protection of the load in the event of a remote programming error, incorrect voltage control adjustment, or power supply failure. The protection circuit monitors the output and reduces the output voltage and current to zero whenever the preset voltage limit is exceeded. The OVP adjustment is accessible from the front of the unit directly below the option indicators at the top left edge of each front panel. Avoid placing undue stress on this control. The trip threshold may be set as low as 3.0V, thus providing load protection at low output voltage levels. A red LED on the front panel indicates when the OVP circuit has been activated.

To set the level at which the output of the unit will be automatically clamped to zero volts, follow this sequence:

a. Turn the OVP control fully clockwise.

b. Adjust the output to the desired trip voltage.

c. Slowly turn the OVP control counterclockwise until the red OVP indicator lamp lights.

d. Turn the POWER switch to OFF.

e. Turn the voltage control knob to minimum.

f. Turn the POWER switch back ON and increase the voltage to check that the power supply shuts off the output at the desired voltage.

An over voltage condition on the output will cause the OVP indicator to light and clamp the output to zero until the over voltage is removed, and power is turned OFF and back ON to reset the OVP circuit. When using OVP equipped units connected in parallel, be sure all OVP controls are set to maximum to avoid damaging the internal OVP crowbar SCR.

2.6.2 Remote ON/OFF (Options M5 & M7)

This feature is useful in test applications since it allows for "soft" ON-OFF control of the output and eliminates the transients and surges associated with mechanically switching the input circuit. The remote ON-OFF control circuit uses a TTL compatible input to remotely control (disable or enable) the power supply output. A logic level signal between pin 15 (positive) and pin 2 (common) on the rear connector determines the output conditions.

TTL LOW = OUTPUT ON
TTL HIGH = OUTPUT OFF

A yellow LED on the front panel indicates when the shutdown circuit is activated. The input line is optically isolated to prevent ground loops and can therefore be accessed by circuits with voltage differentials of up to 500 volts.

2.6.3 Remote Programming (Options M5 & M7)

The voltage and current outputs of the power supply can be programmed by external voltage sources. Zero to full output is linearly proportioned to a 0 to 10V control signal. Before activating the remote program mode, ensure that the voltage and current knobs on the front panel are in their fully counterclockwise position. These controls are disabled during remote programming and cannot be used to control the output.

The remote programming mode is selected by setting the DIP switch accessible from the rear panel as follows:

Closing switch #4 enables external voltage programming.
Closing switch #5 enables external current programming.

For both voltage and current programming, switches 4 and 5 should be closed. A flashing green LED on the front panel indicates when the remote programming mode is enabled.

To control the voltage from zero to full output, a 0 to 10V signal should be applied between pin 17 (positive) and pin 5 (common) on the rear connector (Vv-pgm).

V Gain Equation: Vout = Vv-pgm (Rated maximum output voltage/10)

NOTE

Pins 4 and 5 are at negative sense potential but not connected to it. Do not tie pins 4 or 5 to any other points on the rear connector.

Similarly, to control the current limiting from zero to full output, a 0 to 10 volt signal should be applied between pin 16 (positive) and pin 4 (common) on the rear connector(Vi-pgm). Use a separate isolated supply for voltage and current programming.

I Gain Equation: Iout = Vi-pgm (Rated maximum output current/10)

Any noise or AC component present on the programming source will be amplified by the gain factor of the control stage. Where minimum noise is required a low noise program source must be used, and should be connected to the power supply using a shielded twisted pair.

2.6.4 Isolated Tracking (Option M7)

Isolated tracking is useful where simultaneous turn up, turn down, or proportional control of all power supplies in a system is required. In the tracking mode, the slave units track the master unit linearly.

Closing DIP switch #2 on the rear panel puts individual units into the slave mode. The master unit is selected by closing switch #3. Connection of the master and slave units is made by wiring the tracking bus of all units. The bus is connected to pins 8 and 9 of the rear connector. **The tracking bus is internally connected in multiple units so that external wiring is not required.** In this mode, only the front panel controls of the master unit are enabled. A green LED on the front panel indicates when the tracking circuit is activated in the slave mode. One master unit can drive up to five slave units.

An over voltage condition in one slave supply will not affect the outputs of the other supplies, but an over voltage condition in a master supply will disable all the slave supplies. The outputs of master/slave units may be wired in series as required by the application. Do not connect master/slave units in parallel. For faithful tracking operation, all slave units must be adjusted with respect to the master. The following procedure should be followed:

a.Locate the range and offset trim potentiometers (rear panel Figure 2-3).

b.Set the master voltage to zero.

c.Adjust the offsets of the slave units to zero.

d.Set the master to the full scale voltage.

e.Adjust the range of the slaves to match the master voltage.
f.Repeat steps b to f until the errors are within specification.

2.6.5 Audible Mode Indicator (Option M7)

The audible mode indicator is useful in laboratory test equipment where it is inconvenient to visually monitor the supply while conducting tests, or in system applications where this feature could be used as an alarm function. Three different modes are available and are selected by setting the DIP switch on the rear panel as follows:

Closing #6: Enables audible mode indicator and emits a pulse tone on transition from voltage to current mode or vice versa.

Closing #7 & #6: Selects continuous tone in current mode.

Closing #8 & #6: Selects continuous tone in voltage mode.

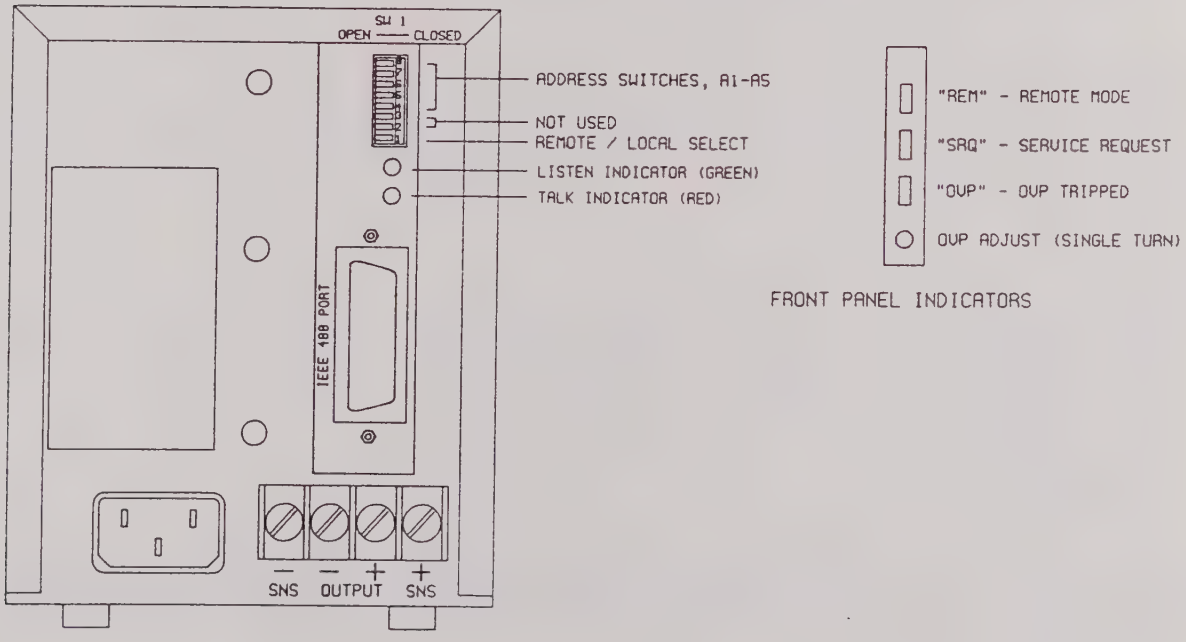
2.7 OPERATION WITH THE IEEE 488 INTERFACE INSTALLED (OPTION M9)

Option M9 provides a microprocessor-based programming interface which allows direct programming of the output voltage and current in volts and amperes with 12-bit resolution using the IEEE standard 488-1978 interface bus (or General Purpose Interface Bus [GPIB]). Over-voltage protection (OVP) and digital read-back of voltage and current to 8-bit precision are standard. This option would normally be used in conjunction with a programmable controller with IEEE 488 capability. The following section details how to program the XT Series power supply with IEEE 488 capability and assumes the operator is familiar with the IEEE 488 bus structure and the particular IEEE 488 controller being used.

See Figure 2-4, and Table 2-2 for details on Option M9 Connector and Controls.

Figure 2-4

Connector, Controls and Indicators



The IEEE 488 interface connects to the IEEE 488 bus with the standard connector system, having the following pin assignment:

Table 2-2
IEEE 488 Interface Connector Detail

Pin		Pin	
1	D101	13	D105
2	D102	14	D106
3	D103	15	D107
4	D104	16	D108
5	EOI	17	REN
6	DAV	18	GND 6
7	NRFD	19	GND 7
8	NDAC	20	GND 8
9	IFC	21	GND 9
10	SRQ	22	GND 10
11	ATN	23	GND 11
12	SHIELD	24	LOGIC GND

2.7.1 Interface Functions

The following interface functions defined by IEEE Standard 488 are implemented:

SH1 Source Handshake
AH1 Acceptor Handshake
T6 Talker
L4 Listener
SR1 Service Request
RL1 Remote Local
PP1 Parallel Poll
DC1 Device Clear
DT1 Device Trigger
E1 Open Collector Drivers

Multi-line Control Functions

The Source Handshake, Acceptor Handshake, Talker, and Listener functions are ordinarily implemented by the interface card and the controller, and require no action by the user. The Listen and Talk indicators on the rear panel turn on when the power supply is addressed to be a listener or talker. (The talker function includes serial poll).

Service Request

Service Request is a uni-line message asserted by the power supply at Power On (nonmaskable), and for certain other events selected by the user; namely, Invalid Syntax, Range Error, Output Disabled, Limit Mode, and Over-Voltage. The power supply powers on with all service requests masked.

The SRQ indicator, a yellow LED on the front panel, turns on at power-on and whenever the power supply requests service from the controller, and remains on until the controller conducts a serial poll. The SRQ indicator remains on if the service request condition remains after a poll. (Note: in Local mode, the SRQ LED will remain on since no serial poll is conducted.)

Serial Poll

In a serial poll, the controller polls each device on the bus, one at a time. The power supply responds with an eight bit status byte on the data lines. The following table defines each bit, indicating what causes the bit to be set and reset, and the state of the corresponding front panel indicators.

Table 2-3
Serial Poll Status Byte

DIO Line	Decimal Weight	Maskable SRQ?	Description	Bit Reset by	Front Panel Indicator
1	1	Yes	OVER-VOLTAGE: Set when OVP circuit trips	Power Off/On if OVP condition ceases	OVP LED on
2	2	Yes	RANGE ERROR: Set when programmed value exceeds model maximum values or soft limits	Serial Poll	-
3	4	-	Not used	Always zero	-
4	8	Yes	LIMIT MODE: Set when unit is programmed for constant voltage "MDV" but switches to constant current "MDC", or vice versa	Serial Poll if the limit mode operation ceases after the SRQ	Mode LEDs show the state of the power supply but not of the limit bit
5	16	Yes	DISABLE: Set when disabled with "S" command	Re-enable with "R", "GO" or device trigger	Voltage & current at zero
6	32	Yes	INVALID: Set for syntax error	Serial Poll	-
7	64	-	REQUEST SERVICE: Set when power supply requests service, indicates whether unit was requesting service when polled	Serial Poll if SRQ condition ceases	SRQ LED on
8	128	No	POWER-ON: Set when unit initializes at power-on	Serial Poll	-

Power-on (PON) always requests service. Therefore, if a momentary power dropout causes the interface memory to lose its programmed values, PON alerts the user that the power supply has been initialized and is in initial mode.

All unmasked status bits will accumulate in the status byte until a serial poll is conducted, regardless of whether that condition still exists. Masked bits will return to zero when polled.

Parallel Poll

Parallel poll allows the controller to determine quickly which of a number of instruments on the bus requested service. The parallel poll response corresponds to bit #7 of a serial poll status byte. Parallel poll does not reset the service request. The power supply must be configured remotely to respond to a parallel poll with either a "1" or "0" on one of the DIO lines if the unit is requesting service.

Remote/Local

The remote/local function allows the power supply to operate in either local or remote (IEEE 488) control. The power supply may be switched from REM to LOC and back to REM without loss of the programmed values. The user can send a Local Lockout to the power supply via the IEEE 488 bus to disable the remote switch on the rear panel. With Local Lockout, the controller determines if the unit operates in local or remote mode. This enables the controller to prevent anyone from returning the power supply to local control.

Device Clear

The power supply will implement Device Clear regardless of whether the unit is in local or remote control. Device Clear is typically used to send all or selected devices to a known state with a single command. The power supply will be set to Initial Conditions after Device Clear.

Device Trigger

Device Trigger will enable the most recently programmed values whether the unit is in local or remote control. If the power supply is in local mode, the new values will be implemented when switched from local to remote control. Device Trigger is typically used to synchronize the operation of a number of addressed devices.

2.7.2 Address Selection

The IEEE 488 bus address switches are located on the rear panel. Any address from 00 to 30 (decimal) is a valid IEEE 488 address. The power supply will operate on whatever address is set on the address switches. The power supply address is the total decimal value of switches selected.

The switches on the rear panel (Figure 2-4) are as follows:

Function	Switch	Address Value Open (Left)	Closed (Right)
A1 (LSB)	8 (top)	1	0
A2	7 .	2	0
A3	6 .	4	0
A4	5 .	8	0
A5 (MSB)	4 .	16	0
-	3 .	-	-
-	2 .	-	-
REM/LOC*	1 (bottom)	LOCAL	REMOTE

* Determines power on condition

2.7.3 Device Dependent Command Set

Device dependent commands are device dependent messages. For the power supply to receive them, they must be sent over the IEEE 488 bus when the power supply has been addressed as a listener.

The following commands are implemented:

V aaa.aaa	Output Voltage
C bbb.bbb	Current Limit
MXV aaa.aaa	Maximum Programmable Voltage
MXC bbb.bbb	Maximum Programmable Current
S	Disable Output
R	Enable Output
GO	Enable Output, Implement Mode Command
MSK cc	Set Service Request Conditions
MD d	Voltage or Current Mode
T	Trigger Read-back

Input Value Range:		Model#	Vmax (Volts)	Imax (Amps)
aaa.aaa	=0 to Vmax	XT7-6	7	6
bbb.bbb	=0 to Imax	XT15-4	15	4
cc	=0 to 63	XT20-3	20	3
d	= V or C	XT30-2	30	2
		XT60-1	60	1
		XT120-0.5	120	0.5

2.7.4 Syntax

a. Spaces within a command are optional.

b. Commands may be sent in any order.

c. Multiple commands separated by commas or semicolons may be sent on one line.

d. Commands must be terminated with EOI, LF EOI, or CR LF EOI. (In most instances, a terminator is automatically transmitted at the end of the controller's output string).

e. Numbers will be truncated after the third decimal position.

f. Leading and trailing zeros will be ignored.

g. Numbers that are not within the listed range will invalidate the command.

h. MXV, MXC, S, R, GO, and MSK are implemented upon receipt of the commands.

i. MD, the mode command, is implemented upon receipt of the GO command.

j. The output commands V and C are implemented upon receipt of a GO, R or Device Trigger command (IEEE 488 addressed command).

k. Commands may be sent in upper or lower case letters.

Any number of digits may be sent, but only six will be used. A decimal point must be sent if needed, but may be left out if not needed. Numbers will be truncated after the third decimal place. Numbers must be unsigned integers or real numbers without exponents.

2.7.5 Initial Conditions

The power supply initializes at power-on with the following conditions:

a.Local or Remote Mode - dependent on the setting of switch #8 ("LOCAL")

b.Programmed Voltage = 0 volts (V0.000)

c.Programmed Current = 0 amps (C0.000) *

d.Soft Voltage Limit = Model Vmax (MXVaaa.aaa)

e.Soft Current Limit = Model Imax (MXCbbb.bbb)

f.Mode = Voltage Mode(MD V)

g.Interrupt Mask = 00 (MSK 00)

*The programmed current limit must be set greater than 0 to enable the output of the power supply in voltage mode.

2.7.6 Device Dependent Command Descriptions

V aaa.aaa - programs the output voltage of the power supply, from 0 to Vmax in volts. The voltage command will be stored if the power supply has been addressed to Listen, but will not be implemented until receipt of a GO, R or Device Trigger command. Note that any subsequent voltage value received by the power supply prior to receipt of a GO, R or Device Trigger command will supersede the previous value.

C bbb.bbb - programs the current limit of the power supply, from 0 to Imax in amperes. Factors described in the preceding paragraph for voltage also apply to current.

NOTE

If the power supply receives an invalid request (syntax error, value out of range or greater than soft limit), the power supply output will remain at its present value. A service request will be generated if the Invalid bit (#6) is unmasked in the SRQ byte.

MXV aaa.aaa
MXC bbb.bbb - sets the maximum output V/I to which the output can be programmed in remote mode. Soft limits protect the load in situations in which a damaging output V/I is inadvertently programmed. If the output V/I values to be programmed are determined by a series of measurements and computations, an unexpected combination of values could result in an unacceptably high output. However, if the V/I values exceed the soft limits, the power supply will consider the new values as an invalid request and the outputs will remain at the previous values.

The soft limit values are compared to all incoming values. If the incoming value is valid, it is stored in the power supply interface buffer. Therefore, if a value is sent to the power supply but not implemented by a GO, R or Device Trigger command, that value will not be affected by any subsequently received soft limit values. (The present programmed output values are also not affected). It is good practice to program soft limit values first, before programming the output.

S (set) - used to disable (turn off) the output of the power supply. An SRQ is generated if the Disable bit (#5) of the SRQ byte is unmasked. The power supply will continue to receive and store commands. The previous value or the most recently programmed output value will be re-enabled upon receipt of a GO, R or Device Trigger command.

R (reset) - used to enable the output of the supply. It implements the V and C commands (but does not implement MDV or MDC commands).

GO - similar to the R (reset) command but implements not only the V and C commands but also the MDV and MDC mode commands. (The IEEE 488 Device Trigger [addressed command] is identical to the GO command and is used to synchronize instruments on the bus).

MSK cc - used to program the power supply to make service requests on user-specified conditions. The two digit code should be an integer from 00 to 63.

00	-All Service Requests masked (disabled)
01	-Over-Voltage
02	-Range Error (out of range or exceeds soft limits)
04	-Not used
08	-Limit Mode
16	-Disabled Output (S command received)
32	-Invalid Request (Syntax error)

The above mask codes can be added, to enable combinations of conditions.

MD d (mode) - designates the power supply as either a voltage source (MDV) or current source (MDC). If not masked, the power supply will request service when:

a.The unit switches to constant current while operating in MDV
or,
b.The unit switches to constant voltage while operating in MDC.

NOTE

The power supply will momentarily switch to constant current mode when a new output voltage value is programmed. The mode sense circuitry will detect this momentary transition and will request service if the Limit Mode bit (#4) is unmasked. (To avoid an SRQ while the output is changing to a new value, the Limit Mode bit should be unmasked after the voltage command has been implemented.)

T (trigger) - causes the power supply to read the present value of output voltage and current. In addition, the mode and status conditions are returned if unmasked.

2.7.7 Read-back Format

N
L C
O V xx.xxV xx.xxA CR LF*
D

Where:

N	- power supply operating normally (no SRQ, or SRQ bits masked)
L	- power supply in limit mode when measurement taken
O	- over-voltage protection tripped
D	- power supply output disabled by "S" command
C	- power supply in constant current mode
V	- power supply in constant voltage mode
xx.xx	- numbers representing output volts and output amps
CR LF	- carriage return, line feed

If the power supply is addressed to talk before a T (trigger) readback command, the following message is sent:

OKAY CR LF*

For proper termination of the readback command the complete output string including CR LF should be read (23 bytes total).

* - EOI is asserted true concurrent with line feed

2.7.8 Sample Programming Session

The following sample command sequences are typical applications of a 488 interface equipped XT series power supply. The underlined control commands are controller dependent, and will vary with different systems.

TTL Testing Sequence using the XT 60-1:

REM	Conduct serial poll to clear the Power On SRQ
SPOLL	
REM	Power supply returns 192 decimal or C0 Hex in SRQ status byte to indicate Power On and Request Service bits had been set
REM	Set soft limits at 6 volts and 1 amp
OUTPUT	"MXV 6.000 ; MXC 1.00"
REM	Set service request for OVP condition
OUTPUT	"MSK 01"
REM	Set output for 5 volts, current limit at 4 amps, enable the output
OUTPUT	"V5.00 ; C4.00 ; R"
REM	Readback actual power supply output values
OUTPUT	"T"
INPUT	
REM	Power supply will return actual values

Battery Charging Sequence using the XT15-4:

REM	Conduct serial poll to clear Power On SRQ
SPOLL	
REM	Power supply returns 192 decimal or C0 Hex
REM	Set output for 14.4 volts, 4 amp current limit
OUTPUT	"V14.4 ; C4"
REM	Set power supply as a current source, Enable output
OUTPUT	"MDC ; GO"
REM	Set service request for Mode Crossover event
OUTPUT	"MSK 8"
REM	Readback actual power supply output values
OUTPUT	"T"
INPUT	
REM	Power supply will return actual voltage and current values

The power supply will now request service when the mode changes from Constant Current to Constant Voltage, when the current drawn by the battery drops below 4 amps.

SECTION 3

THEORY OF OPERATION

3.1 POWER CIRCUIT (A2)

Refer to the schematic diagram (figure 5-2) in section 5 and block diagram (figure 5-1) for the following discussion. The power circuit is found on the A2 assembly circuit board.

3.1.1 Raw Supply Section

Power is applied to the unit via the power switch, line fuse, and power transformer T1. Two raw supply voltages (V and 2V applied to the collectors of power transistors Q1 and Q2 respectively) are provided by the bridge rectifier CR15 and filtered by C16 and C18 to C20.

3.1.2 Auxiliary Supply Section

Isolated secondary windings of T1 also provide power to bridge rectifier CR16 which supplies regulators U4 and U5. U5 and its associated components provide a +14 volt supply voltage, and U4 provides a +5 volt supply for the front panel display circuitry. CR19, CR29, CR18 and C30 form a negative voltage doubler circuit supplying regulator U6. U6 provides a -12 volt supply voltage which is stepped down to -6.2 volts by CR17. The -6.2 volts is used to bias the display circuit ICs U102 and U104.

3.1.3 Pass Element Section

Output power is provided by the two raw supply voltages from CR15 and controlled by power pass transistors Q1 and Q2 and their associated driver transistors Q4 through Q6. This power stage has two modes of operation. As long as the output voltage required is less the voltage supplied to the Q1 collector (via CR8), Q1 acts as the pass element. As the output voltage is increased, Q1 begins to saturate and its base current increases sharply. This increases the voltage at the base of Q5 allowing Q6 to turn on and suppling base current to Q2, which becomes the pass element as Q1 is cut off. The output current and voltage are regulated by the amount of base current allowed to flow into Q4 (for a given load) by the voltage and current control circuits.

3.1.4 Shutdown and Soft Start Circuit

An external shutdown signal on option connector pin P1-9 is able to turn on Q3 and draw current away from the Q4 base via CR11, thus turning off the output of the supply. Similarly, a control ground fault (or return sense line error via U3D) will turn on Q3 via CR7 and turn off the output. Applying -12 volts to CR9 causes a reverse bias across CR10 during normal operation. However, as power is turned off, the -12 volt supply collapses quickly and Q3 is turned on via R34 and CR10. This turns off the output quickly, avoiding output transient surges on power-off.

As the power is turned on, C8 delays turn on of analog gate U1B, which in turn gates U1A on for a short period following power- on. This clamps the input to U3A pin 3 to the negative voltage set by CR3 and R13. A negative voltage at U3A pin 3 causes U3A to go negative and turn off Q4 via CR6, turning off the output. In this manner, the output is held off during power-on for a period determined by the time constant of R14 and C8.

3.1.5 Ten Volt Reference Circuit

U2B and CR12 form a precision +10 volt reference circuit. Negative feedback maintains the zener voltage at U2B pin 6 and steps up the zener voltage by the ratio of R44 and R45 to R43. Calibration of R45 thus

sets the output to a precise +10 volts which is filtered by C4 and C5. CR13 and R46 ensure normal start up on power-on. The +10 volt reference is supplied to the front panel voltage and current controls R119 and R121 which provide 0 to +10 volt adjustable levels to the voltage and current control circuits.

3.1.6 Voltage Control Circuit

The 0 to 10 volt signal from the voltage control (R121) is applied to U3A pin 3 via analog gate U1C. Negative feedback from the output via R8, the positive sense line, and sense resistor R122 sets U3A pin 2 at the same level as U3A pin 3. As the output increases, U3A pin 2 rises, the U3A output goes negative and current is drawn away from Q4 via CR6, thus returning the output to its regulated level. Similarly, as the output decreases, U3A pin 2 falls, the U3A output goes positive, less current is drawn away from Q4 via CR6 and the output is returned to its regulated level. (U3B pin 14 is normally high in the voltage regulating mode.) The output level is set by the reference level at U3A pin 3 and the ratio of R8 to the R5 to R7 resistor string. For a 30 volt model, for example, the ratio of R8 to R5-R7 is approximately 3:1 and a 0 to 10 volt level at U3A pin 3 results in a 0 to 30 volt level on the output, adjustable by voltage control R121.

3.1.7 Current Control Circuit

Output load current is returned to power ground from the output return through current shunt R26. This current information is amplified by the differential amplifier circuit formed by U3C and its associated components. The current level is then compared to the setting of the current limit control (R119) at U3B. The 0 to 10 volt signal from R119 is passed through U1D and divided down to an appropriate level by R18, R20, and R33. As the output current exceeds the setting of the current control, U3B pin 13 rises above U3B pin 12, causing U3B to go negative and turning off Q4. This decreases the output until the load current is equal to the level set by R119. Current regulation is thus obtained and the 0 to 10 volt signal from the current control sets the maximum current from zero to full output.

3.1.8 Mode Monitoring Circuit

During voltage mode operation, CR6 is forward biased, while CR6 is reversed biased during current mode operation. Comparator U2A provides a mode indication level at pin 1 by sensing the polarity of the voltage across CR6. This level is used to turn on either the green voltage mode LED (DS131) or the red current mode LED (DS130) on the front panel.

3.1.9 Output Circuit

The output power is applied to the front panel binding posts via connector lines J1-1 through J1-4. The positive and negative sense points for the voltage control circuit are at connector points J2-8 and J2-9 respectively. It is at these sense points that voltage regulation is maintained by U3A, so that remote sensing is possible by connecting the positive and negative sense lines to the desired power points on the load. When the sense lines are not connected, R122 and R125 provide default sensing at the power output binding posts.

R27 provides the output pre-loading needed to maintain operation of the pass element circuit during low load conditions. CR1 and F1 protect the power supply against reverse biases incorrectly applied to the output.

3.1.10 Return Sense Buffer

U3D buffers the return sense line to provide a buffered control ground point for the voltage control circuit. This allows the proper operation of the output sense protection circuit (Q101 and associated resistors).

3.1.11 Metering Outputs

Resistor divider R23, R24 and R25 provides an appropriately calibrated current monitoring signal to the front panel current display circuit. Similarly, resistor divider R5, R6 and R7 provides an appropriately calibrated voltage monitoring signal to the front panel voltage display circuit.

3.1.12 Remote Programming Capability

The 0 to 10 volt levels from the current and the voltage controls may be switched out of the circuit by analog gates U1C and U1A being turned off via the option connector lines P2-9 and P2-8. Lines P2-1 and P2-2 can then be used by an option board to remotely program the voltage and current control circuits with appropriate 0 to 10 volt programming levels.

3.1.13 Model Identification

The A2 board also provides model information required by an option board at connector lines P3-4 through P3-7. Each model is identified by a coded combination of shorted links at points A, B and C. This is decoded by logic circuitry on the option board.

3.2 METER CIRCUIT (A1)

Refer to the schematic diagram (figure 5-2) in section 5 for the following discussion. The meter circuit is found on the A1 assembly circuit board.

3.2.1 Voltage Display

The analog input signal from the A2 power board is divided down so that 1 mV between P102-7 and P102-5 represents 1 volt at the output of the power supply. This reduced voltage is filtered by R128 and C114 to remove noise and then input to U104, a 3 1/2 digit analog to digital converter. U104 converts the input voltage to a three digit readout on the seven segment LED displays DS104 through DS106. The conversion is performed approximately 3 times per second. (This rate is determined by the value of C106.) The full scale accuracy of the meter is determined by the reference voltage from pin 35 to pin 36 of U104. The reference voltage is derived from the 10 volt reference on the A2 board via the divider R132, R133, and R134.

The bar graph driver IC (U103) and LEDs DS117 through DS126 are used to display transient changes in the output voltage. The full scale reference voltage which corresponds to all ten LEDs being lit is determined by R104 and R113.

3.2.2 Current Display

The current metering function is identical to the voltage metering discussed in section 3.2.1. The analog to digital conversion is performed by U102 and displayed on DS101 through DS103. The transient events are displayed on the current bar graph LEDs DS107 through DS116 which are driven by U101.

3.2.3 Output and Sense Lines

The remote sense lines are internally connected to the main output terminals by R122 and R125.

3.3 OPTION CIRCUITS (A3/A4)

The following paragraphs describe the optional features available for the XT Series power supplies. Refer to the schematic diagrams (figures 5-3 and 5-4) in section 5. The option M5 and M7 circuits are found on the A3 assembly circuit board. The option M9 circuit is on the A4 assembly circuit board.

3.3.1 Over Voltage Protection (A3 board)

The OVP control IC (U309) compares the output voltage to an internal reference voltage. The output voltage is sampled by the OVP set point potentiometer (R115) on the front panel. When the set point voltage exceeds the reference for a period longer than approximately 1 msec, U309 fires Q308, an SCR, which shorts the main output. The crowbar SCR is latched on by the current flowing through R35A and CR309. When Q308 fires, Q307 is turned on via CR325 lighting the red OVP indicator LED on the front panel (DS127). Q307 also forward biases CR308 which shuts down the power supply output.

3.3.2 Remote Programming of Output Voltage and Current (A3 board)

The 0 to 10 volt external voltage programming signal is scaled and buffered by U305B, and clamped by CR314 and CR316. Switch S304 selects the remote voltage programming mode by enabling U307A which connects the programming signal to the power board (A2) and disables the local voltage control potentiometer by driving the output of U306A low.

The 0 to 10 volt external current programming signal is scaled and buffered by U305A and clamped by CR311 and CR315. Switch S305 selects the remote current programming mode by enabling U307B which connects the programming signal to the power board (A2) and disables the local current control potentiometer by driving the output of U306D low.

Both the remote voltage and current programming signals are referenced to a common control ground provided by the voltage follower U308B which is set at the return sense line potential. The control ground line is fused by F301 to limit current to 1/8 Amp maximum. The external programming voltage supplies, therefore, must have outputs that are floating with respect to the programmed supply output.

U306C and U306B function as a 2 Hz oscillator which is enabled when either external program control switch is closed. The oscillator drives Q305 which flashes the green program indicator LED (DS129) on the front panel.

3.3.3 TTL Compatible ON-OFF Control (A3 board)

The input lines for the ON-OFF function are isolated by the optoisolator U304. The external TTL control circuit can be biased up to +500Vdc with respect to line safety ground. The power supply output is turned off when pin 15 of rear connector J305 is +3 volts with respect to J305 pin 2. The +3V signal turns on U304 which turns on Q306 and pulls the external shutdown line on J301-9 high, turning off the power supply via Q2 on the power board (A2), and also lights the yellow shutdown indicator LED (DS128) on the front panel.

3.3.4 Audible Mode Indicator (A3 board)

The input to the Audible Mode Indicator circuit is the MODE signal from the power control circuit board (A2). This input signal is positive for the constant voltage mode and negative for the constant current mode. U303A and U303B are used to gate an astable oscillator consisting of U303C and U303D. Resistor R328 changes the frequency of the oscillator according to the level of the mode line, while Q304 is the driver for transducer DS301. Switch S306 enables or disables the oscillator.

Switches S307 and S308 are used to alter the gating function. When S307 is open, U303B will go low, activating the oscillator when the mode level changes from positive to negative (CV-CC). With S307 closed, U303B will go low when the mode is negative (CC mode). In the same manner, with S308 open, U303B will go low when the mode level changes from negative to positive (CC-CV). With S308 closed, U303B will go low when the mode is positive (CV mode).

3.3.5 Isolated Tracking (A3 board)

This circuit has two modes of operation, either as a master or a slave. In the master mode (S303 closed), the output monitor voltage is input to a voltage to frequency converter (U302). This converter outputs a square wave having a frequency directly proportional to the input voltage. This square wave is then applied to the transistor driver pair Q301 and Q302 which energizes the primary of the pulse transformer T301. T301 electrically isolates the master circuit from any other slaves connected, allowing tracking supplies to be biased up to 500 Vdc apart. The output from the master circuit to the tracking bus is a 13 volt peak-to-peak square wave which has a frequency varying from 10kHz at zero volts output to 50kHz at maximum rated output.

The unit is put into slave mode by closing S302, which disables the master circuit with U307D via CR302. The local voltage control potentiometer is disabled by the output of U306A going low, and the remote programming line is disconnected by U307A. The square wave signal from the secondary of T301 is shaped and buffered by Q303 and then input to a frequency to voltage converter (U301). The voltage from this converter is filtered by R313 and C307 and scaled by U305D to provide a 0 to 10 volt control signal to the power board (A2) via U307C. The gain of this stage is set by R302 and the offset is adjusted by R301. Both these potentiometers are accessible from the rear panel of the power supply.When the slave circuit is enabled, Q305 is turned on by U307D, and the remote program LED (DS129) on the front panel is lit continuously.

3.3.6 IEEE488 Interface (A4 board)

Refer to the schematic diagram (figure 5-4) in section 5 for the following discussion.

The digital portion of the interface card (A4) is energized by an auxiliary power source from the A2 card applied between J3-8 and J3-9. This is rectified and regulated to +5V by CR3 and U7, forming an isolated power supply.

U3 and U4 are bus transceivers which buffer and control the signals to and from the IEEE488 parallel bus through rear connector J5. U6 uses these signals in conjunction with the 8-bit latch U5 to control the microprocessor. Crystal Y1 supplies a stable frequency for the microprocessor clock, C8 provides a power-on reset delay, and U1 provides model information to the microprocessor from the A2 circuit.

Using the internally stored program in U4's EPROM memory, the microprocessor outputs serial information and control signals to two 12-bit D to A converters (U26, U28) through optoisolators U15, U16, U21, U22 and U23. These DACs control the output voltage and current limit of the power supply as follows: The output signal from U28 pin 1 is conditioned by operational amplifiers U27A and U27B and applied to analog gate input U25C. Under software control U4 outputs a high signal on pin 24 turning on the REM indicator on the front panel and turning on analog gate U25A through optoisolator U20. This enables gates U25B and U25C and allows the conditioned DAC output from U28 to be applied to the remote voltage program line to the A2 board (J2-1). At the same time, U20 pulls the remote voltage control line to the A2 low (J2-8). This sets the output of the supply to the desired remotely programmed voltage which is proportional to the U20 (DAC) output. Similarly U26, U27D and U27C control the remotely programmed current through U25B.

The OVP circuit is formed by U29, Q3, Q2 and associated components and operates similarly to the OVP circuit described in section 3.3.1. The MODE signal is applied to the microprocessor through optoisolator U10. The output voltage and current are monitored by U24B and U24A respectively and A to D converters U10 and U17 send this information in serial form to the microprocessor through optoisolator U18. (This readback feature is only available on option M9). U11, U12 and U19 allow the microprocessor to control the readback A to D's with the appropriate control signals.The microprocessor status is displayed by four LED indicators indicating LISTEN, TALK, SERVICE REQUEST, and REMOTE operating modes. The LISTEN and TALK indicators are provided on the rear panel for DE-bugging purposes. An address is assigned to the power supply by switches S4 through S8 through U1 onto the microprocessor data lines. S1 tells the microprocessor to select either IEEE488 remote control or local control by the A2 card. U24D provides a common buffered ground for the analog signal processing circuits. Optoisolator U14 inputs an external OVP signal to U4 when the OVP circuit is activated.

The isolation provided by the optoisolators allows the digital and analog sections to be separated by a potential of up to 500Vdc. This allows operation of multiple units in series or parallel configurations provided the maximum output potential with respect to line safety ground is less than +500Vdc.

SECTION 4

MAINTENANCE

4.1 GENERAL

This section provides troubleshooting and servicing information. The troubleshooting data should be used in conjunction with the schematic diagrams in section 5 and section 3 (which outlines the theory of operation). Any questions pertaining to repair should be directed to Sorensen Company. Include the model and serial numbers in any correspondence. Should it be necessary to return a supply for repair, prior authorization from Sorensen must be obtained.

4.2 PERIODIC SERVICING

Whenever a unit is removed from service, it should be cleaned, using naphtha or an equivalent solvent on metal surfaces, and a weak solution of soap and warm water on the front panel. Compressed air (at 5 psi) may be used to blow dust from in and around components. Refer to section 1.5 for specification verification.

4.3 TEST EQUIPMENT REQUIRED

a. Dual Trace Oscilloscope

b. 4 1/2 digit Digital Multimeter

c. True RMS Voltmeter

d. Variable auto transformer, 500VA

e. 100kHz Frequency Counter

4.4 TROUBLESHOOTING

Refer to sections 3 and 5 for circuit theory and diagrams. Refer servicing to experienced technical personnel only. Discharging of large filter capacitors with suitable resistors is necessary for safety and the protection of components during repair work. Fuses should always be replaced with the same type and rating as originally installed. A blown fuse almost invariably indicates other faulty components which should be identified and replaced before a new fuse is installed. A blown line fuse indicates likely failure of the power bridge rectifier, power transistors Q1 and Q2, and transistors Q3 through Q6, while a blown output fuse indicates likely failure of Q1, Q2, C1 and CR1. Replace power transistors with the identical parts; not with substitutes.

4.4.1 MAIN ASSEMBLY TROUBLESHOOTING CHART
(A1 Front Panel Assembly, and A2 Power Assembly)

- Before using this chart, disconnect any option cards, if the unit is so equipped. If the problem is then eliminated, see the appropriate option troubleshooting section.

- Be sure to observe all cautions mentioned in section 4.4.

- Under the POSSIBLE DEFECTIVE COMPONENTS column, parts are listed in order of decreasing probability of failure.

- All measurements are referenced to ground on P2-6 unless otherwise noted.

- All parts and test points are located on the A2 assembly unless otherwise noted.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS AND CAUSES
NO OUTPUT, AND THE DISPLAY IS BLANK	1) AC VOLTAGE FROM P3-8 TO P3-9 IS 10V +/- 2V.	1a)IF NOTE: INPUT FUSE, POWER SWITCH, INPUT CONNECTOR, TRANSFORMER CONNECTORS b)IF INPUT FUSE IS OPEN; CHECK Q1, Q2, Q4 TO Q6, CR15, CR8 AND F1 BEFORE REPLACING
	2) AUXILIARY DC VOLTAGES SHOULD BE PRESENT AND WITHIN RANGE:	2) CR16, OR;
	P2-7 = - 12V +/- 0.5V	-U6, C29, CR19, CR18
	P2-5 = + 14V +/- 0.5V	-U5
	P3-3 = + 5V +/- 0.5V	-U4
	P1-7 = + 10V +/- 0.1V	-U2, CR12, U3, U1
NO OUTPUT, BUT THE DISPLAY IS LIT	1) CHECK IF OUTPUT FUSE (F1) IS FUNCTIONAL	1a)REVERSE POLARITY VOLTAGE SOURCE CONNECTED TO THE SUPPLY OUTPUT b)Q1, Q2, Q4, Q5, Q6, CR15, U3, CR8
	2) DC VOLTAGE AT U3 PIN 7 (REFERENCED TO NEGATIVE OUTPUT) IS LESS THAN +/- 50mV	2)IF NOT: U3, R125, OR Q101 ON THE A1 ASSEMBLY
	3) WITH VOLTAGE AND CURRENT KNOBS TURNED FULLY CLOCKWISE, DC VOLTAGE AT ANODE OF CR6 IS GREATER THAN 10V	3a)IF NOT AND THE REFERENCE VOLTAGE AT P1-7 IS NOT 10V +/- .1V: U2, CR12 b)OTHERWISE: U3, U1, Q3

	4) DC VOLTAGE AT COLLECTOR OF Q2 IS GREATER THAN THE RATED MAXIMUM OUTPUT VOLTAGE PLUS 2V	4a)IF NOT: CR15 OR TRANSFORMER CONNECTIONS TO PCB. b)IF Q2 COLLECTOR VOLTAGE IS CORRECT: Q1, Q2, CR8, Q4 TO Q6
OUTPUT IS NOT ADJUSTABLE, OR NOT ABLE TO SUPPLY FULL VOLTAGE OR CURRENT.	1) DC REFERENCE VOLTAGE AT P1-7 IS 10V +/-.1V	1a)CHECK THAT VOLTAGE AT P2-5 IS 14V +/- .5V; IF NOT: U5, C26 b)OTHERWISE: U2, U3
	2) DC VOLTAGES AT WIPERS OF R119, R120 (FRONT PANEL CONTROLS) ARE ADJUSTABLE FROM 0 TO 10V	2)IF NOT: FRONT PANEL RIBBON CABLE CONNECTORS R119, R120
	3) VOLTAGE AT COLLECTOR OF Q2 IS GREATER THAN THE RATED MAXIMUM OUTPUT VOLTAGE PLUS 2V AND VOLTAGE AT ANODE OF CR8 IS APPROXIMATELY 1/2 OF VOLTAGE AT Q2 COLLECTOR	3)IF NOT: CR15 OR TRANSFORMER CONNECTIONS TO PCB
	4) VOLTAGE AT THE ANODE OF CR6 IS GREATER THAN 1V WHEN VOLTAGE AND CURRENT KNOBS ARE TURNED CLOCKWISE AND LESS THAN OV WHEN TURNED FULLY COUNTER CLOCKWISE.	4)IF NOT: U3, U1, U2, Q3
	5) OUTPUT VOLTAGE IS ADJUSTABLE FROM ZERO TO MAXIMUM RATED OUTPUT VOLTAGE	5a)IF OUTPUT VOLTAGE IS ABOVE 1/2 OF MAXIMUM OUTPUT VOLTAGE BUT BELOW MAXIMUM OUTPUT VOLTAGE: Q1, Q5, CR8 b)IF ABOVE MAXIMUM OUTPUT VOLTAGE: Q2, Q6, Q4

	6) IF VOLTAGE IS CORRECT WITH NO LOAD BUT DROPS AS LOAD CURRENT INCREASES	6)Q1, Q2, U1, U3
DISPLAY IS ERRATIC OR BLANK BUT THE SUPPLY OUTPUT IS FUNCTIONAL	1) RIBBON CABLE CONNECTORS TO FRONT PANEL ARE PROPERLY SEATED	1)RIBBON CONNECTORS
	2) DC VOLTAGE AT P3-3 IS 5V +/- 0.5V	2)IF NOT: U4
	3) DC VOLTAGE AT ANODE OF CR17 IS -6.2V +/- 0.5V	3a)CHECK IF P2-7 IS -12V +/- .5v, IF NOT: U6, C29, CR19, CR18 b)OTHERWISE:CR17, R51
	4) DC REFERENCE VOLTAGE AT P1-7 IS 10V +/- 0.1V	4)IF NOT: U2, U3, OR, - VOLTAGE DISPLAY: U104 - VOLTAGE BARGRAPH: U103, R113 - CURRENT DISPLAY: U102 - CURRENT BARGRAPH: U101

4.4.2 OPTION M5 OR M7 TROUBLESHOOTING CHART
(A3 Option Assembly - Analog Programming Card)

- Connect the A3 assembly in question to a power supply that is known to be operational to ensure that any problems are on the option board.

- Be sure that all connectors are properly oriented and correctly seated.

- All parts and test points are on the A3 assembly unless otherwise noted.

- All voltages are referenced to control ground at the anode of CR327 unless otherwise noted.

- Before beginning troubleshooting, check that the voltage between control ground (anode of CR327) and the negative output terminal is less than +/- 50mV. If this voltage is exceeded, replace U308.

- Parts are listed in the POSSIBLE DEFECTIVE COMPONENTS column in order of decreasing probability of failure.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS AND CAUSES
NO OUTPUT VOLTAGE AT REAR PANEL CONNECTOR BUT THE FRONT PANEL OUTPUT IS CORRECT	1) F302 IS FUNCTIONAL	1) IF NOT: F301, REVERSE POLARITY VOLTAGE SOURCE CONNECTED TO SUPPLY, OR PARALLEL CONNECTED SUPPLY ON DURING OVP CONDITION
OVP IS ALWAYS TRIPPED (RED LED IS ON)	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS FULLY CLOCKWISE, AND POWER WAS CYCLED OFF/ON	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U309 PIN 8 IS LESS THAN 0.2V	2)IF NOT: U309 OTHERWISE: Q308, Q307
OVP WILL NOT TRIP	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS TURNED FULLY COUNTERCLOCKWISE, AND SUPPLY OUTPUT VOLTAGE IS SET AT GREATER THAN 3V	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U309 PIN 8 IS GREATER THAN 2V	2) IF NOT: U309, R115 ON A1 ASSEMBLY OTHERWISE: Q308, CR309, CR325
REMOTE SHUTDOWN IS NOT FUNCTIONAL	1) WITH 3V PRESENT FROM J305-15 (+) TO J305-2 (-) THE VOLTAGE AT ANODE OF CR307 IS GREATER THAN 10V	1) IF NOT: U304, Q306
	2) IF THE SUPPLY OUTPUT IS DISABLED	2) IF NOT: CR307, Q3 ON A2 ASSEMBLY

	3) WITH 0V PRESENT FROM J305-15 TO J305-2 THE VOLTAGE AT ANODE OF CR307 IS LESS THAN 0.2V	3) IF NOT: U304, Q306
	4) IF THE SUPPLY OUTPUT IS ENABLED	4) IF NOT: Q3 ON A2 ASSEMBLY
THE AUDIBLE MODE INDICATOR IS NOT FUNCTIONAL (OPTION M7 ONLY)	1) MODE INDICATING LED's ON FRONT PANEL CORRECTLY INDICATE VOLTAGE OR CURRENT MODE	1) IF NOT: U2 ON A2 ASSEMBLY OTHERWISE: U303, Q304
THE REMOTE VOLTAGE OR REMOTE CURRENT PROGRAMMING IS NOT FUNCTIONAL	1) WITH 10V APPLIED TO THE VOLTAGE PROGRAM INPUT (J305-17 & J305-5) OR TO THE CURRENT PROGRAM INPUT (J305-16 & J305-5) THE VOLTAGE AT CATHODE OF CR321 (VOLTAGE) OR CR322 (CURRENT) IS 9.5V +/- .2V	1) IF NOT: U305, F301
	2) VOLTAGE AT U307 PIN 1 (VOLTAGE PROGRAM) OR U307 PIN 3 (CURRENT PROGRAM) IS 9.5V +/- 0.2V	2) IF NOT: U307, S304, S305 OTHERWISE: U306, OR U1 ON A2 ASSEMBLY
ISOLATED TRACKING; SLAVE CIRCUIT IS NOT FUNCTIONAL (SEE SECTION 2.6.4 TO CALIBRATE SLAVE UNITS) (OPTION M7 ONLY)	1) TURN "SLAVE" SWITCH ON, TURN "MASTER" SWITCH OFF, AND CONNECT J305-19 AND J305-20 (TRACKING BUS) TO THE CORRESPONDING PINS ON A FUNCTIONING MASTER UNIT. USING AN ANALOG OSCILLOSCOPE, CHECK FOR PRESENCE OF A 10kHz TO 50kHz 2Vp-p SQUARE WAVE ON U301 PIN 11.	1) IF NOT: Q303, T301

	2) VOLTAGE AT U305 PIN 12 IS LESS THAN 0.1V WHEN TRACKING FREQUENCY IS 10kHz AND ABOUT 3V +/-0.5V AT 50kHz	2) IF NOT: U301, OR TRY ADJUSTING R301 (OFFSET) THROUGH FULL RANGE
	3) VOLTAGE AT CR324 CATHODE IS 9.5V +/- 0.2V AT 50kHz AND LESS THAN 0.1V AT 10kHz	3) IF NOT: TRY ADJUSTING R302 (RANGE) AND R301 (OFFSET), U305
	4) VOLTAGE AT U307 PIN 9 IS AS IN STEP #3	4) IF NOT: U307, S302
	5) IF GREEN PROGRAM LED IS LIT	5) IF NOT: U307, Q305, DS129 ON A1 ASSEMBLY
ISOLATED TRACKING; MASTER CIRCUIT IS NOT FUNCTIONAL (OPTION M7 ONLY)	1) TURN "SLAVE" SWITCH OFF AND "MASTER" SWITCH ON. VOLTAGE AT U308 PIN 1 IS LESS THAN 0.1V WHEN THE SUPPLY OUTPUT IS SET TO 0V AND IS 9.5V +/- 0.2V WHEN THE SUPPLY OUTPUT IS SET TO THE RATED MAXIMUM OUTPUT VOLTAGE.	1) IF NOT: U308
	2) USING AN OSCILLOSCOPE, CHECK U302 PIN 10 FOR A 10kHz +/- 1kHz SQUARE WAVE WHEN THE SUPPLY IS SET TO 0V AND FOR 50kHz +/- 1kHz WHEN THE SUPPLY IS SET TO THE RATED MAXIMUM OUTPUT VOLTAGE. THE VOLTAGE SHOULD BE 10 TO 14Vp-p.	2) IF NOT: U302, R314, OR TRY ADJUSTING C309
	3) USING AN OSCILLOSCOPE, CHECK FOR A SQUARE WAVE AS IN STEP #2 AT THE EMITTER OF Q301 0R Q302	3) IF NOT: U307, Q301, Q302

	4) USING AN OSCILLOSCOPE, CHECK FOR A SQUARE WAVE AS IN STEP #2 FROM J305-8 T0 J305-9	4) IF NOT: S303, T301
	NOTE: SOME DISTORTION AND ROUNDING OF THE CORNERS IS NORMAL FOR THE SIGNALS IN STEPS 2 TO 4.	

4.4.3 Option M9 Troubleshooting Chart
(A4 Option Assembly - IEEE 488 Programming Card)

- Connect the A4 assembly in question to a power supply that is known to be operational to ensure that any problems are on the option board.
- Disconnect all unused equipment from the IEEE 488 bus and use a known good IEEE 488 cable securely seated to the rear connector.
- Check that all ICs, cables, and connectors are properly oriented and correctly seated.
- All parts and test points are on the A4 assembly unless otherwise noted.
- All voltages are referenced to control ground at U24 pin 14 in the analog section or to ground at C5 (-) in the digital section unless otherwise noted.
- Before beginning troubleshooting, check that the voltage at J1-5 is less than +/- 50mV. If this voltage is exceeded, replace U24. Also check for +5V across C5 to ensure power supply to the digital section. If this voltage is not correct, check U7 or ICs in the digital section which are abnormally warm to the touch and replace them as necessary.
- Parts are listed in the POSSIBLE DEFECTIVE COMPONENTS column in order of decreasing probability of failure.

SYMPTOM	CHECK	POSSIBLE DEFECTIVE COMPONENTS OR CAUSES
OVP IS ALWAYS TRIPPED (RED LED IS ON)	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS FULLY CLOCKWISE, AND POWER WAS CYCLED OFF/ON	1) J4 CONNECTOR, OVP POT

	2) VOLTAGE AT U29 PIN 8 IS LESS THAN 0.2V	2) IF NOT: U29 OTHERWISE: Q3, Q2
OVP WILL NOT TRIP	1) J4 CONNECTOR TO THE FRONT PANEL IS PROPERLY SEATED, OVP POT IS TURNED FULLY COUNTERCLOCKWISE, AND SUPPLY OUTPUT VOLTAGE IS SET AT GREATER THAN 3V	1) J4 CONNECTOR, OVP POT
	2) VOLTAGE AT U29 PIN 8 IS GREATER THAN 2V	2) IF NOT: U29, R115 ON A1 ASSEMBLY OTHERWISE: Q3, CR8, U14, CR6
SRQ LED IS OFF AFTER POWER-ON RESET	1) PGM (front), TALK AND LISTEN (rear) LEDs TURN ON MOMENTARILY DURING POWER-ON	1) DS128
	2) U4 PIN 11 HAS A FREQUENCY SIGNAL AT ABOUT 733kHz	2) IF NOT: Y1, C6, C7, C8, Q4, U4
NO RESPONSE TO A SERIAL POLL; WILL NOT LISTEN OR TALK	1) INCORRECT ADDRESS SET ON THE REAR PANEL ADDRESS SWITCHES	1) S8 TO S4 SETTINGS
	2) LISTEN AND TALK LEDs REMAIN OFF	2) U1, U5, U6, U2, U3, U4
UNIT WILL NOT GO INTO REMOTE MODE	1) S1 IS SET TO REMOTE	1) S1 SETTING
	2) U4 PIN 24 IS HIGH	2) IF NOT: Q1, U20, U25 OTHERWISE: U6, U5, U4
UNIT LISTENS BUT NO OUTPUT VOLTAGE OR CURRENT	1) COMMAND SYNTAX IS CORRECT	1) COMMAND SYNTAX ERROR
	2) CURRENT AND VOLTAGE LIMITS SET ABOVE ZERO	2) IF NOT: LIMIT SETTINGS
	3) CORRECT OUTPUT VOLTAGE IN VOLTAGE CONTROL MODE	3) IF NOT: R16, R14, U28, U23, U22, U16, U15, U27, U25, U8, U9

4.5.4 A4 Assembly Calibration

CALIBRATION COMPONENT	PARAMETER AFFECTED
R8 (V GAIN)	Voltage readback full scale level - Iterative with R32.
R9 (I GAIN)	Current readback full scale level - Iterative with R31.
R14 (V OFF)	Voltage programming offset - Adjust at 5% programmed output voltage for best linearity. Iterative with R16.
R15 (I OFF)	Current programming offset - Adjust at 5% programmed output current for best linearity. Iterative with R17.
R16 (V ADJ)	Voltage programming full scale level - Iterative with R14.
R17 (I ADJ)	Current programming full scale level - Iterative with R15.
R31 (I ZERO)	Current readback offset - Adjust at 5% output current for best linearity. Iterative with R9.
R32 (V ZERO)	Voltage readback offset - Adjust at 5% output voltage for best linearity. Iterative with R8.

SECTION 5

DRAWINGS AND PARTS LISTS

5.1 GENERAL

This section provides schematic drawings and parts lists for the following assemblies:

A1 - Front panel assembly
A2 - Power assembly
A3 - Option M5 or M7 assembly
A4 - Option M9 assembly
Main assembly - includes all subassemblies

5.2 PARTS ORDERING

Parts may be ordered from the factory using the Sorensen part numbers listed in the following parts lists. Order parts from:

SORENSEN COMPANY
5555 N. Elston Avenue
Chicago , IL
60630
TEL: (312) 775-0843
FAX: (312) 775-7432

ASSEMBLY INTERCONNECTION DIAGRAM

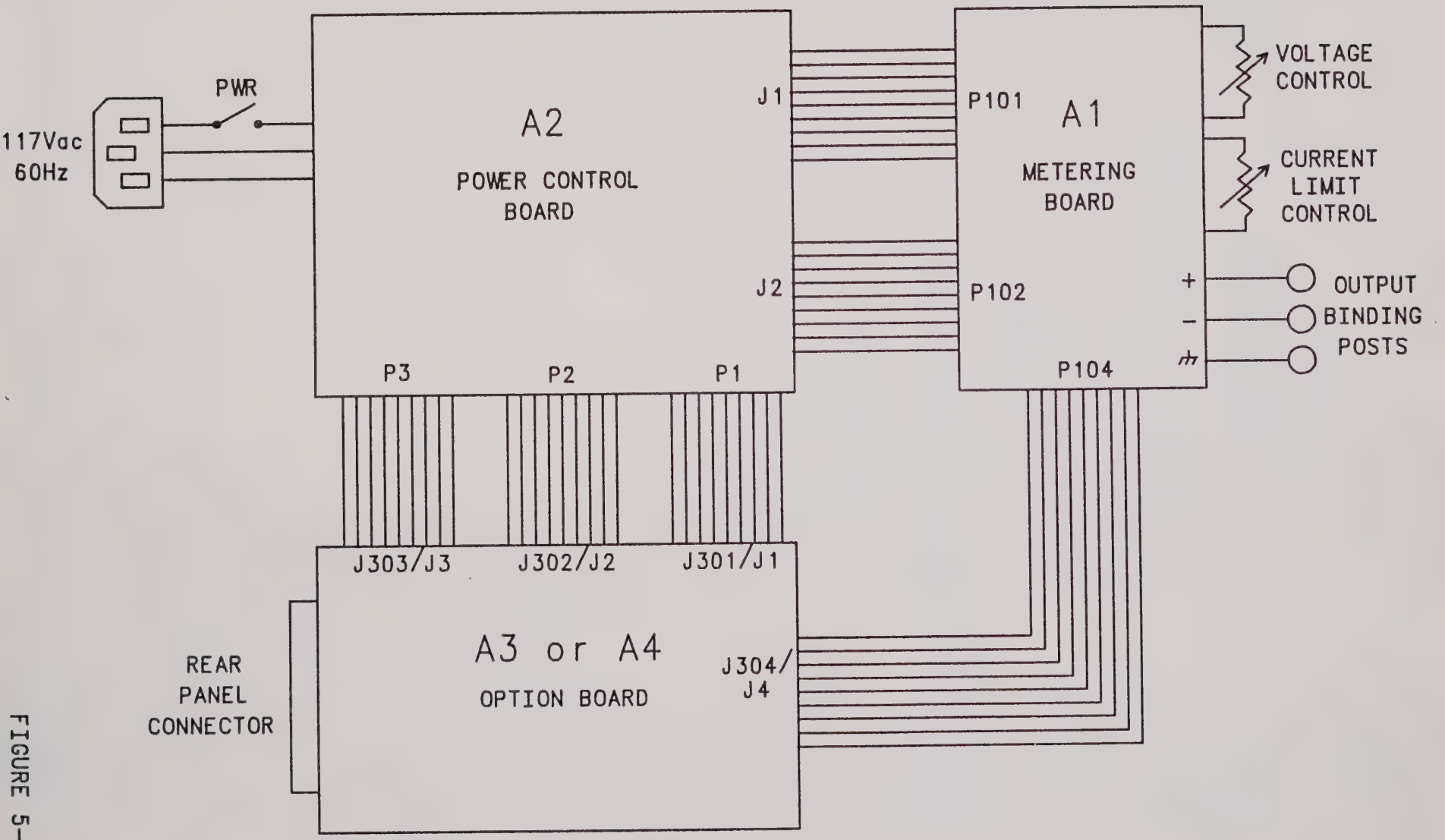


FIGURE 5-1

5.3 A1 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C101,C102	10uF 25V EL RAD 2.5mm	1060677
C103,C105	0.1uF 50V CER RAD 2.5mm	1060736
C104,C106	100pF 100V CER RAD 2.5mm	1060825
C107-C109	0.1uF 50V CER RAD 2.5mm	1060736
C110,C111	47nF 50V CER RAD 2.5mm	1060826
C112	0.1uF 50V CER RAD 2.5mm	1060736
C113,C116	0.1uF 100V MET FILM 10mm	1060827
C114,C115	47nF 50V CER RAD 2.5mm	1060826
C117	0.1uF 250V MET FILM 10mm	1060827
C118,C119	0.1uF 50V CER RAD 2.5mm	1060736
DS101-DS106	Seven segment display red	1061317
DS107-DS127	Red rectangular LED	1060832
DS128	Yellow rectangular LED	1060833
DS129,DS131	Green rectangular LED	1060834
DS130	Red rectangular LED	1060832
P101,P102,P104	9 Pin male connector	1060732
Q101	MPSA92 Transistor	1060835
R101,R102	360 ohm 1/4W 5% (R101 not installed on 120 - 0.5) (R102 not installed on 7-6, 120-.5)	1060836
R102A	360 ohm 1/4W 5% (Installed on 7-6 model only)	1060836
R103 (7-6)	1.5k 1/4W 5%	1060765
R103 (15-4)	820 ohm 1/4W 5%	1060757
R103 (20-3)	620 ohm 1/4W 5%	1060840
R103 (30-2)	390 ohm 1/4W 5%	1060837
R103 (60-1)	180 ohm 1/4W 5%	1060838
R103 (120-0.5)	1.1k 1/4W 5%	1060839
R104(7-6)	1.8k 1/4W 5%	1061318
R104 (15-4)	270 ohm 1/4W 5%	1060956
R104 (20-3)	390 ohm 1/4W 5%	1060837
R104 (30-2)	620 ohm 1/4W 5%	1060840
R104 (60-1)	1.5k 1/4W 5%	1060765
R104 (120-0.5)	220 ohm 1/4W 5%	1060961
R105	5.1k 1/4W 5%	1060841
R106,R107	2.7k 1/4W 5%	1060842
R108	Selected value	
R109	100k 1/4W 5%	1060742
R110	5.1k 1/4W 5%	1060841
R111,R112	2.7k 1/4W 5%	1060842
R113	Selected value	
R114 (7-6)	18k 1/4W 5%	1061319
R114 (15-4)	36k 1/4W 5%	1060844
R114 (20-3)	7.5k 1/4W 5%	1060843
R114 (30-2)	12k 1/4W 5%	1061320
R114 (60-1)	16k 1/4W 5%	1060958

Designation	Description	Part Number
R114 (120-0.5)	18k 1/4W 5%	1061319
R115 (60-1)	1M ohm 1 turn potentiometer	1060984
R115 (120-0.5)	1M ohm 1 turn potentiometer	1060846
R115	100k 1 turn potentiometer (All other models)	1060845
R116	100k 1/4W 5%	1060742
R117	Selected value	
R118	Not used	
R119	5k 1 turn potentiometer	1060847
R120	470k 1/4W 5%	1060779
R121	5k 10 turn potentiometer	1060848
R122	150 ohm 1/4W 5%	1060849
R123-R125	22k 1/4W 5%	1060850
R126,R128	100k 1/4W 5%	1060742
R127	470k 1/4W 5%	1060851
R129-R131	Not used	
R132	8.25k 1/4W 1%	1060852
R133	Selected value	
R134	1k 1/4W 1%	1060745
U101,U103	LM3914N IC	1060853
U102,U104	ICL7107 IC	1060854
	Molded plastic knob	1060855
	Latex hose, 3/16" I.D.	1060856
	Red display filter	1060857
	Molded plastic front panel	1060858
	6-32x1/4" self tap screw	1060859
	Red binding post	1060861
	Black binding post	1060863
	Green binding post	1060864
	#6 Internal lockwasher	1060866
	A1 Printed circuit board	1060866
	Sense connection eyelet	1060867
	Component lead socket	1060885
	40 Pin IC socket	1060868
	Top label, no options	1060869
	Top label, option M5 or M7	1061321
	Top label, option M9	1060871
	Bottom label, with switch	1060872
	Bottom label, without switch	1060873
	Model label (Replace XXXX with model)	1061322

5.4 A2 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C1 (7-6)	100uF 63V EL RAD	1060680
C1 (15-4)	100uF 63V EL RAD	1060680
C1 (20-3)	100uF 63V EL RAD	1060680
C1 (30-2)	33uF 100V EL RAD	1061077
C1 (60-1)	10uF 100V EL RAD	1061078
C1 (120-0.5)	3.3uF 160V EL RAD	1061079
C2	1nF 50V CER RAD 5mm	1061080
C2A (7-6)	100pF 100V CER RAD 5mm	1060689
C2A	22pF 100V CER RAD 5mm (All other models)	1061081
C3	10uF 25V EL RAD LOW LKG	1061082
C3A	47pF 100V CER RAD 5mm	1060710
C4	10uF 25V EL RAD	1060677
C5,C6	0.1uF 50V CER RAD 5mm	1060675
C7	47nF 50V CER RAD 5mm	1061083
C8	1nF 50V CER RAD 5mm	1060880
C9,C10	0.1uF 50V CER RAD 5mm	1060675
C11 (120-0.5)	100pF 100V CER RAD 5mm	1061084
C13 (120-0.5)	220pF 100V CER RAD 5mm	1061085
C11,C13	47pF 100V CER RAD 5mm (All other models)	1060710
C12	100pF 100V CER RAD 5mm	1060689
C14 (60-1)	4.7nF 100V CER RAD 5mm	1060742
C14 (120-0.5)	4.7nF 200V CER RAD 5mm	1061086
C14	4.7nF 50V CER RAD 5mm (All other models)	1060688
C15	10uF 25V EL RAD	1060677
C15A(120-0.5)	2.2nF 50V CER RAD 5mm	1060899
C15A	1nF 50V CER RAD 5mm (All other models)	1060700
C16,C18 (60-1)	1OuF 50V EL RAD	1061088
C16,C18(120-0.5)	10uF 100V EL RAD	1061089
C16,C18	10uF 25V EL RAD (All other models)	1060677
C16A	3.3uF 50V EL RAD	1061090
C17	10uF 25V EL RAD	1060677
C19 (7-6)	2000uF 10V EL RAD	1061091
C19	All other models: not used	
C20,C21 (7-6)	22000uF 10V EL RAD	1061091
C20,C21 (15-4)	15000uF 16V EL RAD	1061092
C20,C21 (20-3)	15000uF 25V EL RAD	1061093
C20,C21 (30-2)	10000uF 25V EL RAD	1061094
C20,C21 (60-1)	3300uF 50V EL RAD	1061095
C20,C21(120-0.5)	1000uF 100V EL RAD	1061096
C22 (7-6)	22000uF 10V EL RAD	1061091
C22 (15-4)	15000uF 16V EL RAD	1061092
C22	All other models: not used	
C23	2200uF 16V EL RAD	1060679
C24	1uF 250V MET FILM 15mm	1061097
C25	0.1uF 50V CER RAD 5mm	1060675

Designation	Description	Part Number
C26	220uF 25V EL RAD	1060679
C27	10uF 25V EL RAD	1060677
C28	Not used	
C29,C30	470uF 35V EL RAD	1060683
C31	4.7nF 50V CER RAD 5mm	1060688
CR1	1N5402 Rectifier diode	1061099
CR2	Not used	
CR3,CR4	1N4148 Diode	1060711
CR5	Not used	
CR6,CR7	1N4148 Diode	1060711
CR8 (7-6)	MUR1620CT Rectifier diode	1061100
CR8 (15-4)	MUR1620CT Rectifier diode	1061100
CR8 (20-3)	MR751 Rectifier diode	1060901
CR8 (30-2)	1N5402 Rectifier diode	1061099
CR8 (60-1)	1N4005 Rectifier diode	1060903
CR8 (120-0.5)	1N4005 Rectifier diode	1060903
CR9	1N5240A Zener diode	1060720
CR10,CR11	1N4148 Diode	1060711
CR12	1N825A Zener diode	1061101
CR13	1N4148 Diode	1060711
CR14	Not used	
CR15 (7-6)	MDA2501 Bridge rectifier	1061102
CR15 (15-4)	MDA2501 Bridge rectifier	1061102
CR15 (20-3)	MDA2501 Bridge rectifier	1061102
CR15 (30-2)	1N5402 Rectifier - 4 pieces	1061099
CR15 (60-1)	1N5402 Rectifier - 4 pieces	1061099
CR15 (120-0.5)	1N4005 Rectifier - 4 pieces	1060903
CR16	VM28 Bridge rectifier, 1 Amp	1060946
CR17	1N4735A Zener diode	1060713
CR18,CR19	1N4005 Rectifier diode	1060903
CR20	1N4148 Diode	1060711
F1	GLH 7 Fuse, 7 Amp fast blow	1060906
J1	3.5" MASCON Cable assembly	1060724
J2	4.5" MASCON Cable assembly	1060725
P1-P3	9 Pin male connector	1060732
Q1 (120-0.5)	MJ11018 Transistor	1061105
Q1	2N6577 Transistor (All other models)	1061106
Q2 (60-1)	MJ11018 Transistor	1061105
Q2 (120-0.5)	MJ11018 Transistor	1061105
Q2	2N6577 Transistor (All other models)	1061106
Q3	2N3904 Transistor	1060909
Q4 (120-0.5)	MPSA42 Transistor	1061107
Q4	2N5550 Transistor (All other models)	1061108
Q5,Q6	MPSA92 Transistor	1060835

Designation	Description	Part Number
R1	820 ohm 1/4W 5%	1061109
R2,R3 (7-6)	14.3k 1/4W 1%	1061110
R2,R3 (15-4)	9.53K 1/4W 1%	1061111
R2,R3 (20-3)	11.3k 1/4W 1%	1061112
R2,R3 (30-2)	7.68k 1/4W 1%	1061113
R2,R3 (60-1)	3.83k 1/4W 1%	1061114
R2,R3(120-0.5)	11.3k 1/4W 1%	1061112
R4 (7-6)	16.9k 1/4W 1%	1061115
R4	10M 1/4W 5% (All other models)	1060959
R5 (120-0.5)	140 ohm 1/4W 1%	1061116
R5	1k 1/4W 1% (All other models)	1060745
R6 (7-6)	6.19k 1/4W 1%	1061117
R6 (15-4)	32.4k 1/4W 1%	1061087
R6 (20-3)	23.7k 1/4W 1%	1061118
R6 (30-2)	15.8k 1/4W 1%	1060747
R6 (60-1)	7.32k 1/4W 1%	1060748
R6 (120-0.5)	5.76k 1/4W 1%	1061119
R7 (7-6)	1.33k 1/4W 1%	1061120
R7 (15-4)	30.1k 1/4W 1%	1060749
R7 (20-3)	22.6k1/4W 1%	1061121
R7 (30-2)	15.0k 1/4W 1%	1060750
R7 (60-1)	7.50k 1/4W 1%	1060751
R7 (120-0.5)	5.23k 1/4W 1%	1061122
R8 (7-6)	1.47k 1/4W 1%	1061123
R8 (15-4)	36.5k 1/4W 1%	1060752
R8 (20-3)	52.3k 1/4W 1%	1061124
R8 (30-2)	68.1k 1/4W 1%	1060753
R8 (60-1)	84.5k 1/4W 1%	1060754
R8 (120-0.5)	130k 1/4W 1%	1061125
R9,R10	100k 1/4W 5%	1060742
R11	10k 1/4W 1%	1060759
R12	Not used	
R13	1.5k 1/4W 5%	1060765
R14-R17	470k 1/4W 5%	1060851
R17A	4.7k 1/4W 5%	1060790
R18	Selected value	
R19	Not used	
R20	6.65k 1/4W 1%	1061126
R21	4.7k 1/4W 5%	1060790
R22	100k 1/4W 1%	1060769
R23	Selected value	
R24 (7-6)	Jumper wire	1061127
R24 (15-4)	Jumper wire	1061127
R24 (20-3)	909 ohm 1/4W 1%	1061129
R24 (30-2)	909 ohm 1/4W 1%	1061129
R24 (60-1)	909 ohm 1/4W 1%	1061129
R24 (120-0.5)	140 ohm 1/4W 1%	1061130
R25	1k 1/4W 1%	1061131
R26 (7-6)	0.12 ohm 6W 5%	1061132
R26 (15-4)	0.12 ohm 6W 5%	1061132

Designation	Description	Part Number
R26 (20-3)	0.2 ohm 5W 5%	1061133
R26 (30-2)	0.2 ohm 5W 5%	1061133
R26 (60-1)	0.2 ohm 5W 5%	1061133
R26 (120-0.5)	1.2 ohm 5W 5%	1061134
R27 (7-6)	39 ohm 5W 5%	1061135
R27 (15-4)	100 ohm 5W 5%	1061136
R27 (20-3)	200 ohm 5W 10%	1061137
R27 (30-2)	470 ohm 5W 10%	1061138
R27 (60-1)	2k 5W 10%	1061139
R27 (120-0.5)	10k 5W 10%	1061140
R28,R29	1k 1/4W 5%	1060743
R30	20k 1/4W 5%	1060744
R31	390 ohm 1/4W 5%	1060837
R32	100k 1/4W 1%	1060769
R33	10k 1/4W 1%	1060759
R34	100k 1/4W 5%	1060742
R35-R37	1k 1/4W 5%	1060743
R36A	Jumper wire, #22	1061127
R37A	2k 1/4W 5%	1061142
R38	Selected value	
R39 (7-6)	1k 1/4W 5%	1060743
R39	2k 1/4W 5% (All other models)	1061142
R40	390 ohm 1/4W 5%	1060837
R41	130 ohm 1/4W 5%	1061143
R42	511 ohm 1/4W 1%	1061144
R43	10k 1/4W 1%	1060759
R44	4.99k 1/4W 1%	1061145
R45	Selected value	
R46	510 ohm 1/4W 5%	1060756
R47	100 ohm 1/4W 5%	1060793
R48	1.5k 1/4W 5%	1060765
R49	150 ohm 1/4W 5%	1061146
R50	100k 1/4W 5%	1060742
R51	390 ohm 1/4W 5%	1060837
R52	470 ohm 1/4W 5%	1060921
T1	Power transformer (Replace XXXX with model)	1061147
U1	4066B IC	1060929
U2	LM358N IC	1060927
U3	LM347N IC	1060853
U4,U5	LM317T IC	1061148
U6	LM7912CT IC	1061149
	TO-3 Insulating washer	
	Extruded heatsink	1061150
	Nylon grommet	1060881
	#6x3/8" Type A screw	1060868
	#6x5/8" Type B screw	1061151
	#6 Internal lockwasher	1060866
	#8 Ring tongue	1061012

Description	Part Number
TO-3 Transistor socket	1061152
A2 Printed circuit board	1061153
TO-220 Board mtg. heatsink	1061154
TO-220 Clip on heatsink	1061155
Component lead socket	1060885
Fuse clip	1060978
14 Pin IC socket	1060891
8 Pin IC socket	1060890
18 AWG yellow TEW wire	1061156
18 AWG blue TEW wire	1061157
18 AWG red TEW wire	1061158
18 AWG green TEW wire	1061014
Fast-on connector	1060878
#8 KEP nut	1061159
6-32x1/4" Pan head screw	1061160
#6 KEP nut	1060873
1/4" Clear heatshrink	1060879

5.5 A3 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C301*	0.1uF 50V CER RAD 5mm	1060675
C302*	0.33uF 50V CER RAD 5mm	1060706
C303*	22pF 100V CER RAD 5mm	1060894
C304*	2.2nF 100V CER RAD 5mm	1060685
C305*	3.3uF 25V TANT RAD	1060895
C306*	0.1uF 250V MET FILM 10mm	1060704
C307*	0.1uF 50V CER RAD 5mm	1060675
C308	Not used	
C309*	2-15pF Trim capacitor	1060897
C310*	100pF 100V CER RAD 5mm	1060896
C311*	0.1uF 50V CER RAD 5mm	1060675
C312*,C313*	33nF 50V CER RAD 5mm	1060898
C314	10uF 25V EL RAD	1060677
C315*	2.2nF 50V CER RAD 5mm	1060899
C316*	0.33uF 50V CER RAD 5mm	1060706
C317,C318	2.2nF 100V CER RAD 5mm	1060685
C319-C321	0.1uF 50V CER RAD 5mm	1060675
C322	0.33uF 50V CER RAD 5mm	1060706
C322A*	1uF 35V TANT RAD	1060895
C323-C325	0.1uF 50V CER RAD 5mm	1060675
C326	2.2nF 100V CER RAD 5mm	1060685
C327	0.1uF 50V CER RAD 5mm	1060675
C328*,C330*	0.1uF 50V CER RAD 5mm	1060675
C329*	100pF 100V CER RAD 5mm	1060896
C331,C332	3.3uF 25V TANT RAD	1060900
C333,C334	Not used	
C335	220pF 100V CER RAD 5mm	1061323
C336	1uF 35V TANT RAD	1060895
CR301*,CR302*	1N4148 Diode	1060711
CR303	Not used	
CR304*-CR306*	1N4148 Diode	1060711
CR307-CR309	1N4148 Diode	1060711
CR309	MR751 Rectifier diode	1060901
CR310,CR311	1N4148 Diode	1060711
CR312	Not used	
CR313	1N4735A Zener diode	1060902
CR314-CR324	1N4148 Diode	1060711
CR325	1N4005 Rectifier diode	1060903
CR326,CR327	1N4148 Diode	1060711
DS301*	QMB06 Transducer	1060904
F301	1/8 Amp picofuse	1060905
F302	GLH 7, 7 Amp fast blow fuse	1060906
J301,J302,J304	3.5" MASCON Cable assembly	1060723
J305	25 Pin female D-Sub.connector	1060907

* on Option M7 only

Designation	Description	Part Number
P301*	4 Pin male connector	1060908
Q301*,Q303*	2N3904 Transistor	1060909
Q302*,Q304*	2N3906 Transistor	1060910
Q305,Q307	2N3906 Transistor	1060910
Q306	2N3904 Transistor	1060909
Q308	2N6402 SCR	1060911
Q309*	2N3904 Transistor	1060909
R301*,R302*	50k Trim potentiometer	1060912
R303*	10k 1/4W 5%	1060767
R304*,R306*	10k 1/4W 5%	1060767
R305*	4.7k 1/4W 5%	1060790
R307*,R308*	100k 1/4W 5%	1060742
R309*,R311*	47k 1/4W 5%	1060851
R310*	300k 1/4W 5%	1060762
R312*,R313*	100k 1/4W 5%	1060742
R314*	Selected value	
R315*	2.2M 1/4W 5%	1060913
R315A*	2k 1/4W 5%	1060914
R316*	300k 1/4W 5%	1060762
R317	Not used	
R317A*	4.7k 1/4W 5%	1060790
R318*	3.3M 1/4W 5%	1060755
R319*	1M 1/4W 5%	1060794
R320*	3.3M 1/4W 5%	1060755
R321*,R322*	100k 1/4W 5%	1060742
R323*	1M 1/4W 5%	1060794
R324*	47k 1/4W 5%	1060768
R325*	100 ohm 1/4W 5%	1060793
C326*	220k 1/4W 5%	1060915
R327*	390k 1/4W 5%	1060916
R328*	1M 1/4W 5%	1060794
R329	10k 1/4W 5%	1060767
R330	1k 1/4W 5%	1060743
R331,R332	47k 1/4W 5%	1060768
R333,R334	1k 1/4W 5%	1060743
R335	220 ohm 1W 5%	1060917
R336	1k 1/4W 5%	1060743
R337	1M 1/4W 5%	1060794
R338,R341	953k 1/4W 1%	1060918
R339,R340	39.2k 1/4W 1%	1060919
R342,R343	47k 1/4W 5%	1060768
R344*	220k 1/4W 5%	1060915
R345*	7.50k 1/4W 1%	1060751
R346*	100k 1/4W 5%	1060742
R347*	10k 1/4W 1%	1060767
R348	100k 1/4W 5%	1060742
R349	390k 1/4W 5%	1060916
R350-R353	1M 1/4W 5%	1060794

* on Option M7 only

Designation	Description	Part Number
R351A*	220k 1/4W 5%	1060915
R354	1k 1/4W 5%	1060743
R355,R357	47k 1/4W 5%	1060768
R356	10k 1/4W 5%	1060767
R358	200 ohm 1/4W 5%	1060920
R358A	1k 1/4W 5%	1060743
R359	470 ohm 1/4W 5%	1060921
R360	Jumper wire	1060922
R361	1M 1/4W 5%	1060794
R362*	10k 1/4W 5%	1060767
R363*	3.3M 1/4W 5%	1060755
R364*	47k 1/4W 5%	1060768
R365	Not used	
R366*	10k 1/4W 5%	1060767
R367	100 ohm 1/4W 5%	1060793
R368	10k 1/4W 5%	1060767
R369*	4.7k 1/4W 5%	1060790
S301-S308	8PST Piano DIP switch	1060923
T301*	Pulse transformer	1060924
U301*,U302*	TSC9400 IC	1060925
U303*	4001B IC	1060926
U304	4N37 IC	1060855
U305	LF347N IC	1060853
U306	4001B IC	1060926
U307	4066B IC	1060929
U308	LM358N IC	1060927
U309	MC3423P IC	1060928
	A3 Printed circuit board	1060930
	Component lead socket	1060885
	14 Pin IC socket	1060891
	8 Pin IC socket	1060890
	Fuse clip	1060931
	#6x3/8" Type A screw	1060868
	4-40x5/16" Pan head screw	1060864
	4-40x1/4" KEP nut	1060865
	Female screwlock ass'y kit	1060932
	A3 assembly subplate	1060933
	Magnetic shield	1060934
	Nylon grommet	1060881
	6-32x5/16" Pan head, black	1060870
	25 Pin male D-Sub. connector	1060935

* on Option M7 only

5.6 A4 ASSEMBLY REPLACEMENT PARTS

Designation	Description	Part Number
C1-C3	0.1uF 50V CER RAD 2.5mm	1060936
C4	2200uF 16V EL AXIAL12.5x30mm	1060937
C5	10uF 25V EL RAD 2.5mm	1060677
C6,C7	15pF 100V CER RAD 5mm	1060938
C8	4.7uF 25V EL RAD 2.5mm	1060939
C9-C19	0.1uF 50V CER RAD 2.5mm	1060936
C20	2.2nF 100V CER RAD 5mm	1060685
C21,C22	1nF 100V CER RAD 5mm	1060961
C23,C24	0.1uF 50V CER RAD 5mm	1060936
C25	22pF 100V CER RAD 5mm	1060941
C26	4.7nF 100V CER RAD 5mm	1060942
C27-C29	0.1uF 50V CER RAD 2.5mm	1060936
C30	22pF 100V CER RAD 5mm	1060941
C31	4.7nF 100V CER RAD 5mm	1060942
C32	0.1uF 50V CER RAD 2.5mm	1060936
C33,C34	3.3uF 25V TANT RAD	1060900
CR1	Green T-1 3/4 LED	1060944
CR2	Red T-1 3/4 LED	1060945
CR3	VM28 Bridge rectifier	1060946
CR4,CR5	1N4148 Diode	1060711
CR6	1N4005 Rectifier diode	1060903
CR7,CR9,CR10	1N4148 Diode	1060711
CR8	MR751 Rectifier diode	1060901
F1	GLH 7 Fuse, 7 Amp fast blow	1060906
J1-J4	3.5" MASCON Cable assembly	1060724
J5	IEEE488 Connector	1060947
J6	9 Pin male connector	1060732
J7	4 Position barrier strip	1060948
Q1	2N3904 Transistor	1060909
Q2	2N3906 Transistor	1060910
Q3	2N6402 SCR	1060911
R1	470 ohm x 9 SIP	1060951
R2	130 ohm 1/4W 5%	1061324
R3	390 ohm 1/4W 5%	1060837
R4	Not used	
R5	10k 1/4W 5%	1060767
R6,R7	470 ohm x 9 SIP	1060951
R8,R9	1k potentiometer, multiturn	1060953
R10,R11	5.36k 1/4W 1%	1061325
R12,R13	4.32k 1/4W 1%	1061326
R14-R17	1k potentiometer, multiturn	1060953
R18	10k 1/4W 5%	1060767
R19	470 ohm 1/4W 5%	1060921
R20,R21	1k 1/4W 5%	1060743
R22	470 ohm 1/4W 5%	1060921

Designation	Description	Part Number
R23	100k 1/4W 5%	1060742
R24	47k 1/4W 5%	1060768
R25	10k 1/4W 5%	1060767
R26	10k 1/4W 1%	1060759
R27	100 ohm 1/4W 5%	1060793
R28	33k 1/4W 5%	1061327
R29	10k 1/4W 5%	1060767
R30	10M 1/4W 5%	1060959
R31,R32	1k potentiometer, multiturn	1060953
R33	7.87k 1/4W 1%	1060960
R34,R36-R38	100k 1/4W 1%	1060769
R35	1.3k 1/4W 5%	1060766
R39	470k 1/4W 5%	1060779
R40	470 ohm x 9 SIP	1060951
R41,R42	100 ohm 1/4W 5%	1060793
R43,R44	10k 1/4W 5%	1060767
R45,R46	47k 1/4W 5%	1060768
R47,R49	220 ohm 1/4W 5%	1060961
R48	1.3k 1/4W 5%	1060766
R50	470 ohm 1/4W 5%	1060921
R51	36.5k 1/4W 1%	1060752
R52,R53	100k 1/4W 1%	1060769
R54,R55	1k 1/4W 1%	1060745
R56	36.5k 1/4W 1%	1060752
R57	220 ohm 1/4W 5%	1060961
R58,R59	10k 1/4W 5%	1060767
R60	220 ohm 1/4W 5%	1060961
R61	Jumper wire, #22	1061127
S1	8 Pos. piano DIP switch	1060923
U1	74LS541 IC	1060963
U2,U3	MC3447 IC	1060964
U4 (Option 15)	8749 IC	1060965
U4 (Option M9)	8750 IC	1060966
U4 Piggy back	2732 IC (Option 16 only)	1060967
U5	74LS573 IC	1060968
U6	7210 IC	1060969
U7	LM317T IC	1061148
U8,U9	7417 IC	1060971
U10	ADC0831 IC (Option M9 only)	1060972
U11-U16	4N37 IC (U11,U12 omitted on option 15)	1060855
U17	ADC0831 IC (Option M9 only)	1060972
U18-U23	4N37 IC (U18,U19 omitted on option 15)	1060855
U24	LF347 IC	1060853
U25	4066B IC	1060929
U26,U28	MP7543 IC	1060974
U27	LF347 IC	1060853
U29	MC3423 IC	1060928

Designation	Description	Part Number
Y1	11MHz Crystal	1060975
	#6x3/8" Type A screw	1060868
	6-32x1/4" Pan head screw	1060976
	#6 KEP nut	1060873
	IEEE connector hardware kit	1060977
	Fuseclip	1060931
	Barrier strip retaining clip	1060979
	TO-220 Heatsink	1060980
	A4 assembly subplate	1060981
	A4 printed circuit board	1060982
	6 Pin IC socket	1060983
	8 Pin IC socket	1060890
	14 Pin IC socket	1060891
	16 Pin IC socket	1060892
	20 Pin IC socket	1060984
	24 Pin IC socket	1060985
	40 Pin IC socket	1060986
	LED right angle mount	1060987
	Fast-on terminal	1060878
	22 AWG red TEW wire	1060988
	22 AWG black TEW wire	1060989
	18 AWG red TEW wire	1060990
	18 AWG black TEW wire	1060991
	Cable tie, 4"	1060992

5.7 MAIN ASSEMBLY REPLACEMENT PARTS

Description	Part Number
A1 assembly, 7-6 model	1058952-1
A1 assembly, 15-4 model	1058952-2
A1 assembly, 20-3 model	1058952-3
A1 assembly, 30-2 model	1058952-4
A1 assembly, 60-1 model	1058952-5
A1 assembly, 120-.5 model	1058952-6
A2 assembly, 7-6 model	1058953-1
A2 assembly, 15-4 model	1058953-2
A2 assembly, 20-3 model	1058953-3
A2 assembly, 30-2 model	1058953-4
A2 assembly, 60-1 model	1058953-5
A2 assembly, 120-.5 model	1058953-6
A3 assembly, option M5	1058954-1
A3 assembly, option M7	1058954-2
A4 assembly, option M9	1061328
Single baseplate	1058941-1
Dual baseplate	1058941-2
Triple baseplate	1058941-3
Quad baseplate	1058941-4
Quad side panel	1058943-1
Single cover	1058942-1
Dual cover	1058942-2
Triple cover	1058942-3
Quad cover	1058942-4
MDL 2 1/2 Fuse, 2 1/2 Amp slow	1058950-1
Power switch	1058948-1
Power switch bracket	1061009
Power switch push rod	1058947-1
AC Powercord	1058956-1
MATE N LOK socket housing	1061328
MATE N LOK socket pin	1061330
MATE N LOK plug housing	1061331
MATE N LOK plug pin	1061332
Fuseholder	1060931
AC Input connector housing	1061333
AC Input connector pin	1061004
Fast-on connector, 0.110"	1061334
Fast-on connector, 1/4"	1060878
4-40x1/4" Flat head screw, black	1061011
4-40x1/4" Type F screw	1061010
4-40x5/8" Flat head screw, black	1061335
#4 Internal lockwasher	1060862

Description	Part Number
#4 KEP nut	1060865
6-32x1/8" Pan head screw	1061336
6-32x3/16" Pan head screw	1061337
6-32x1/4" Pan head screw	1060976
6-32x1/4" Pan head screw, black	1030976
#6 KEP nut	1060873
8-32x1/4" Flat head screw	1061338
8-32x5/16" Stainless steel screw	1061339
#8x1/2" Type A flat head, black	1061340
#8 Ring tongue	1061012
8-32 Type U spring nut	1061341
8-32x.35" Hex spacer	1061342
#18 AWG green TEW wire	1061014
#18 AWG white TEW wire	1061015
#18 AWG black TEW wire	1060991
Heatshrink tubing, 1/4" clear	1060879
Rubber foot, 1/2"x5/16"	1061019
Rubber foot, 3/4"x1/2" (quad)	1061020
Handle webbing	1061343
Handle clip	1058945-1
Serial number label	1061023
Red caution label,	1061024
Fuse rating label 1061344	

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